FOR

AVIONICS INTERMEDIATE COURSE

CLASS C7

UNIT XI

CNTT-M1558

PREPARED BY

NAVAL AIR TECHNICAL TRAINING CENTER
NAVAL AIR STATION MEMPHIS
MILLINGTON, TENNESSEE

PREPARED FOR

NAVAL TECHNICAL TRAINING COMMAND

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11-10-1S	STUDENT ACTIVITY GUIDE
11-10-1I	INFORMATION SHEET

Principles of Radar

INTRODUCTION: The purpose of this assignment is to familia ize the student with the basic fundamentals of pulse radar systems. A thorough knowledge of the basics involved in radar range determinatior is necessary for the technician to effectively test and evaluate the more complex systems.

Along with the knowledge of radar range determination principles the technician must be familiar with the associated terminology and its relationship to system characteristics.

LESSON TOPIC LEARNING OBJECTIVES:

11.1.1 Given statements concerning the factors that affect maximum free space range of a radar as stated in the Basic Radar Equation, select the correct statement(s).

11.1.2 Given a formula sheet and the values of pulse width and pulse repetition frequency solve for the values of minimum range and maximum unambiguous range.

11.1.3 Given specified radar characteristics, solve for the pulse width.

11.1.4 Given specified radar characteristics, solve for pulse repetition frequency.

11.1.5 Given specified radar characteristics, solve for average power.

11.1.6 Given statements concerning the factors that affect the ability of a radar receiver to detect the preser of an echo pulse, select the limiting factor(s).

11.1.8 Given statements concerning the controlling factors of azimuth resolution, select the correct statements(s).

Read, Reintjes and Coate Principles of Radar,
Edition, McGraw-Hill, 1952 Chapter 1, p
thru 53.

Skolnik, M. L, Introduction to Radar Sy
McGraw-Hill, 1962, Chapter One and Two,
to pp 70

COMPLETE: STUDENT ACTIVITY GUIDE 11.1.1S

STUDY QUESTIONS:

1. Define the term Radar, and the principle by
is able to measure the distance.

2. Solve for the time required for a radar's tr
mitted wave to travel to an object, a distan
9800 meters from the radar, and return.

__________ is the major assembly of the radar system which establishes the center spectral frequency of operation for the radar.

__________ is the major assembly of the radar system which establishes the time base for accurate range measurement.

__________ is the major assembly of the radar system which establishes the pulse repetition frequency (PRF).

Solve for the pulse repetition frequency (PRF) for a radar system operating with a duty cycle (DC) of .00013 and a pulse width (PW) of 4.5 microsecond.

The range resolution of a radar system is:

a) Improved by decreasing the pulse repetition frequency (PRF).
b) Limited by the antenna beamwidth on shortrange operation.
c) Limited by the pulse duration on longrange operation.
d) Limited by the pulse duration at all times.

With a 2.5 microsecond pulse duration, an object extending 16 meters in length to the radar will create an indicator echo pip covering.

a) 750 meters on the range scale.
b) 40 meters on the range scale.
c) 375 meters on the range scale.
d) 2460 meters on the range scale.

Solve for the pulse width (PW) of a radar system operating on the 150km range with a duty cycle of .001 and a pulse repetition frequency (PRF) of 1000Hz.

__________ microseconds

A radar system is operating with a transmit time of 4.5 microseconds. Solve for the distance that must

i. With reference to question h, solve for the minimum detection range.

__________ meters

j. Solve for the maximum unambiguous range of a radar system operating on a high PRF of 1420Hz

__________ meters

k. "Second time around echoes" are best reduced by:

a) Varying the pulse repetition frequency.
b) Increasing the pulse width.
c) Decreasing receiver sensitivity.
d) Decreasing the pulse width.

l. Solve for the peak power (P_{pk}) of a radar system having a maximum duty cycle (DC) of .00014 and an average power (Pave) of 630 watts

__________ watts

m. In order to double the free-space maximum range of a radar system the peak transmitter power must be

a) Doubled
b) Increased by a factor of four.
c) Increased by a factor of sixteen.
d) Decreased by a factor of four.

n. ______ ______ is the primary limiting factor in a radar receiver's ability to detect weak echo returns.

o. A radar system with a conical beam pattern of 1.5 is scanning a small target aircraft at 11km. The radars system's scan rate is 250 rpm. Solve for the width of the target aircraft as it would appear on the radar's indicator.

__________ meters

of Radar Modulators and the different m
of charging a PFN. Review the listed l
objectives, then test yourself with the
study questions provided.

LESSON TOPIC LEARNING OBJECTIVES:

11.2.1 Given the five characteristics of a Radar Modul
Pulse and a list of their effect on Radar perfo
correctly match the characteristic to it's effe
Radar performance.

11.2.2 Given statements concerning d-c resistance meth
charging of a pulse forming network (PFN), sele
the correct statement(s).

11.2.3 Given statements concerning d-c resonant method
charging of a PFN without a charging diode, sel
the correct statement(s).

11.2.4 Given statements concerning d-c resonant method
charging of a PFN using a diode, select the cor
statement(s).

11.2.5 Given statements concerning the function of and
reason for the inverse diode in a Line Pulsing
Modulator, select the correct statement(s).

11.2.6 Given statements concerning the function of and
theory of operation of the Thyratron in a modul
select the correct statement(s).

11.2.7 Given statements concerning the function of the
Pulse Transformer in a Radar Modulator, select
correct statement(s).

11.2.8 Given a schematic diagram of a typical Line Pul
Modulator with appropriate values, solve for R_m

11.2.9 Given a schematic diagram of a typical Line Pul
Modulator with appropriate values, solve for PR

.11 Given a schematic diagram of a typical Line Pulsing Modulator with appropriate values, solve for Z_o.

DY ASSIGNMENT:

1. Read NAVPERS 10318-D Aviation Electronics Technician 1 & C, pp 256-268

2. Study notes taken in class.

PLETE: STUDENT ACTIVITY GUIDE 11.2.1S

DY QUESTIONS:

1. Name the three common methods of controlling the discharge time of PFN's.

2. What are the advantages/disadvantages of d-c resistance charging of a PFN? Of d-c resonant charging?

3. Why are Bifilar windings commonly used in the Pulse Transformer?

4. What is frequency pulling?

5. What is frequency pushing?

a. it is impossible to measure the delay in an actual line
b. an actual line would be too long for most applications
c. Actual lines are too costly
d. actual lines are inefficient

2. Charging a PFN utilizing a charging diode and an a-c source, the efficiency is approximately:

a. 25% less than d-c Resistance charging
b. 20% more than d-c Resonance charging
c. 25% greater than a-c Resonant charging
d. 20% greater than d-c Resistance charging

3. The duration of the Modulator's pulse depends upon:

a. the applied voltage
b. the values of inductance and capacitance in each LC section
c. the values of inductance and capacitance in each LC section and the number of LC sections
d. the deionization time of the Thyratron

4. Addition of charging diode to the resonant charging circuit permits the storage element to charge to:

a. a d-c voltage twice the applied d-c voltage
b. 95% of the applied d-c voltage
c. 180% of the applied d-c voltage
d. the value of the applied voltage and to remain constant until discharged

5. A Pulse Forming Network's switching device must have which of the following characteristics?

a. close and open within microseconds
b. conduct large currents and withstand large voltage
c. consume only a fraction of the power that passes within it
d. All of the above

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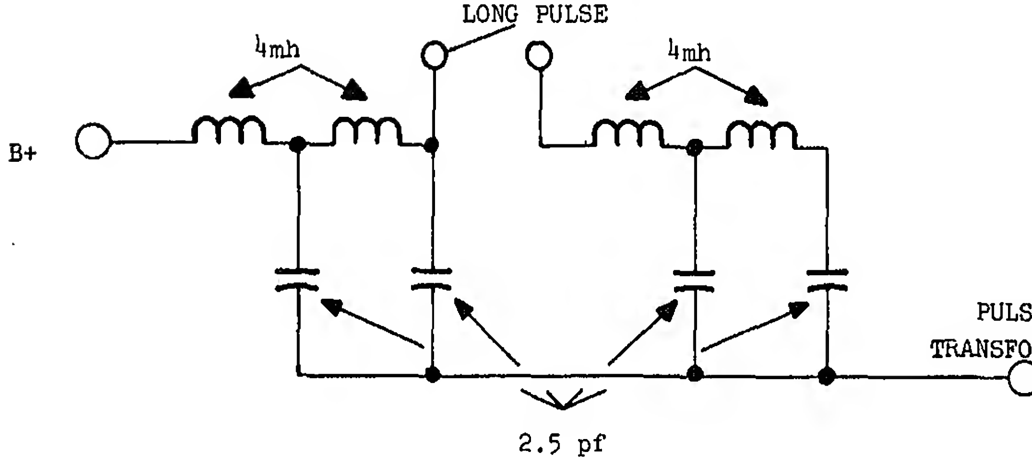
Figure 2



6 . Calculate the Pulse Width of the Pulse Forming Network shown in figure 2.

a. 0.1 μsec

b. 0.2 μsec

c. 0.4 μsec

d. 0.8 μsec

7 . Using the Values shown in figure 2 with the long pulse switch engaged, calculate the Pulse Width of the Pulse Forming Network with the Long Pulse switch engaged.

a. 0.4 μsec

b. 0.6 μsec

c. 0.7 μsec

d. 0.8 μsec

11.3.2 Given statements concerning the location of the TR- tubes and their respective junctions within the rad waveguide assembly, select the correct statement(s)

11.3.3 Given statements concerning balanced duplexer opera select the correct statement(s).

11.3.4 Given a schematic representation and statements con the operation of a ferrite duplexer select the corr statement(s) that describe(s) the direction and the of phase shift offered to a signal by various paths the device.

11.3.5 Given statements concerning the purpose of SHUTTERS the correct statement(s).

STUDY ASSIGNMENT:

Read: Information Sheet 11.3.1I Duplexers

Complete: Student Activity Guide 11.3.1S

STUDY QUESTIONS: Refer to Student Activity Guide

State the advantages of the Ferrite Duplexer.

What is the purpose of the shutter.

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A. Duplexers

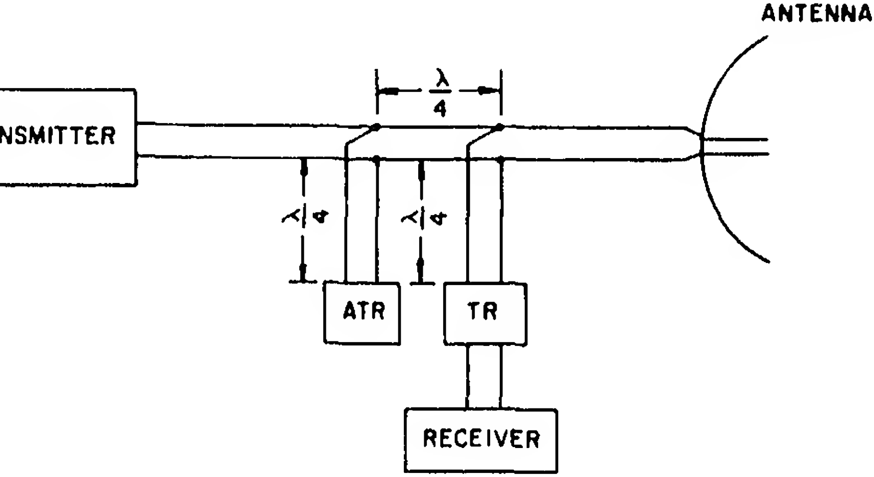
The duplexer is the device that (1) switches the r antenna to either the transmitter or the receiver and serves to protect the receiver from burnout or damage transmission. Duplexers are generally gas-discharge d but ferrites and solid-state varactor diodes have also used. Several forms of passive duplexers using the pr of hybrid junctions or polarization rotation were disc Sec. 3.2. In this section, active duplexers using som switching element are discussed. In a typical applica transmitter power might be 10 watts and the maximum sa at the receiver might be a few watts. Therefore the must provide, in this instance, on the order of 60-db between transmitter and receiver, with only negligible in the transmitted power.

Branch-type Duplexers. The principle of the bran duplexer is illustrated in Figure 1. It consists of transmit-receive (TR) switch and an anti-transmit-rec switch, both of which are gas-discharge tubes. When mitter is turned on, the TR and the ATR tubes ionize; they break down, or fire. The TR in the fired condit as a short circuit to prevent transmitter power from the receiver. Since the TR tube is located a quarter from the main transmission line, it appears as a shor at the receiver but as an open circuit at the transmi and does not impede the flow of transmitter power. T of the TR, therefore, is to disconnect the receiver f transmitter during transmission and to protect the re from excess power.

The ATR breaks down on transmission along with th Since it is displaced a quarter wavelength from the m mission line, the short circuit produced by the ATR c fired condition appears as an open circuit on the tra line. Thus the ATR has no effect on transmission.

During reception the transmitter is turned off; n TR nor the ATR is fired. The open circuit of the ATR located a quarter wave from the transmission line and as a short circuit across the line. If the apparent circuit is located a quarter wave from the receiver b line, the transmitter is effectively disconnected fro and the echo signal power is directed toward the rece

gap is well suited as a TR switch since its impedance is
in the unfired condition and low when fired. It is not
satisfactory, however, from a practical point of view. Its
acteristics change with use; it must be adjusted at frequent
rvals; and its life is limited.



RE 1. Principles of branch-type radar duplexer. The TR
ides receiver protection and switching; the ATR channels
echo power into the receiver.

performance of the simple spark-gap TR can be improved by
osing it is a partially evacuated glass envelope operated
in a properly designed cavity. By enclosing the spark gap
in a glass (or other suitable material) envelope, at a gas
sure of a few millimeters of mercury, both the breakdown
age and the operating voltage are reduced.

The gas filling used in the TR tube must ionize and deionize
kly and easily. It is in trying to meet these requirements
the TR tube designer sometimes encounters difficulty. In
r to obtain a short deionization time, the electrons formed
he discharge must be removed quickly once the RF power is
ed off. Although electrons may be removed by direct recom-
tion with the positive ions to form neutral atoms, this
ess is not too favorable and long recovery times are the
lt. If the recovery is to be rapid, some third body must
resent, such as a neutral atom or the walls of the discharge
, to act as a catalyst. One method of speeding recovery is
mploy a gas with a high affinity for electrons; for example,

argon and water vapor have also been used. A TR tube filled with a pur noble gas like argon has low breakdown voltage and offers good receiver protection and relatively long life. However, conventional TR tubes filled with pure noble gases have relatively long deionization times (on the order of milli-seconds) and are not suitable, except for long-range radar applications (satellite or ballistic-missile detection), where it is not necessary to detect targets at short ranges.

Recombination times may be improved by the presence of the tube walls or other surfaces. In some tubes quartz wool is located in the discharge region for this purpose. It consists of very fine fibers and has a large surface-to-volume ratio. Quartz wool is especially useful in tubes filled with the pure noble gases. Surface recombination permits a recovery time in argon on the order of 50 μsec. Even shorter recovery times have been reported with argon TR tubes especially designed to improve recovery by surface recombination. The arc loss in argon-filled tubes is exceptionally low compared with the loss in water-vapor-filled tubes.

The TR is not a perfect switch; some transmitter power always leaks through to the receiver. The envelope of the RF leakage pulse might be similar to that shown in Figure 2. A

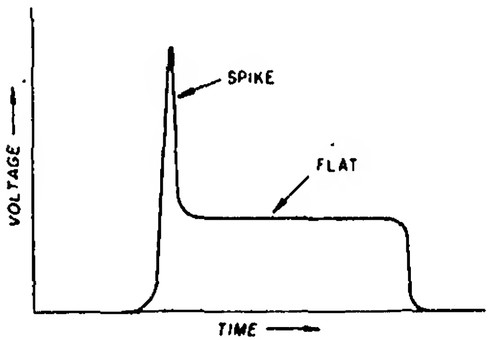


FIGURE 2 Example of leakage pulse through a TR tube.

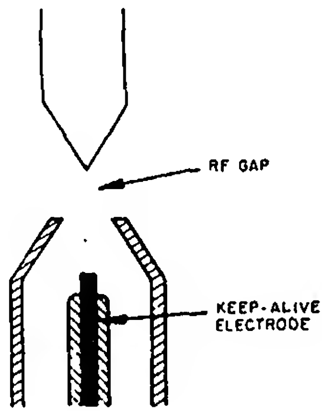


FIGURE 3 TR tube electrode showing arrangement of the keep-alive.

To ensure reliable and rapid breakdown of the TR tube upon application of the RF pulse, an auxiliary source of electrons is often supplied to the tube. An electron source can be obtained with a weak "keep-alive" d-c discharge between an additional electrode introduced into the tube and one of the electrodes of the TR (Fig. 3). Electrons from the keep-alive dishcarge diffuse into the TR gap, where they act to trigger the breakdown once RF power is applied.

The keep-alive generates noise just as does any other gas-discharge device. If too strong a discharge is maintained the noise level might be high enough to degrade the receiver sensitivity.

An example of a typical TR tube is shown in Figure. 4. It consists of a length of waveguide sealed at both ends with glass or ceramic windows transparent to microwave frequencies. Two TR gaps formed by the truncated cones, spaced a quarter of a guide wavelength apart, provide greater bandwidth than possi with a single TR gap. The truncated cones and the baffles for a resonant-filter section. The cones are the capacitive eleme and the baffles are the inductive elements. The prime functic of the filter section is to aid the breakdown process by producing a relatively high value of electric field strength in the region of truncated cones. Not only does the use of two T gaps lead to greater bandwidth than is possible with a single gap, but the amount of power which leaks through during the flat portion of the pulse is less since both gaps are fired ar contribute to the attenuation. Each of the two windows is matched with an inductive iris. They are of lower Q than the TR gaps and, being spaced a quarter wavelength from each of th TR gaps, act to further increase the bandwidth. The keep-ali discharge is placed in the gap farthest from the transmitter. In operation, the gap with the keep-alive discharge breaks do first, followed by the breakdown of the remaining gap and the breakdown at the input window nearest the transmitter. The main discharge takes place at the input window.

The attenuation during the gap is determined by the disch at the input and at each of the two gaps. Teh combined atten- uation can be on the order of 80 to 100 db. Leakage energy i the initial spike is determined by the design of the keep-ali gap and by the nature and pressure of the gas fill. Arc loss depends primarily upon the characteristics of the input windo

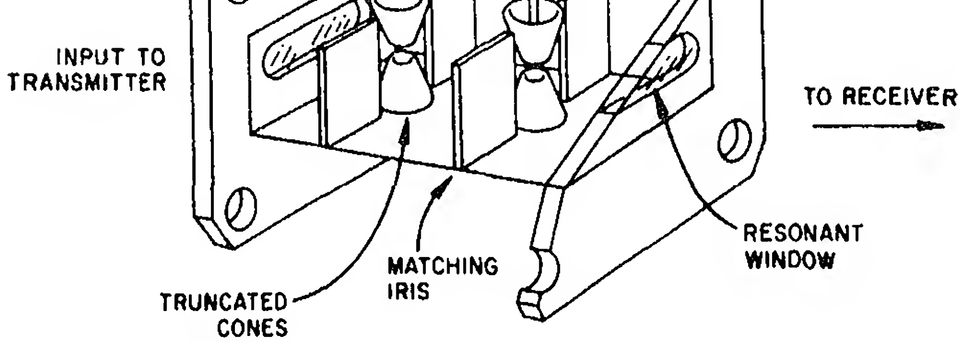


FIGURE 4 Example of a typical TR tube.

The gas-fill pressure for minimum are loss and recovery time i contrary to that required for minimum spike and flat leakage. These functions can be separated by using a gas-filled glass capsule sealed to the input window which provides a separate and distinct gas fill for the input window.

One of the factors limiting the life of TR tubes is the disappearance, or "clean-up," of the gas filling. Clean-up i the gradual decrease of pressure caused by the chemical combi tion of the gas with the electrodes and by the gas molecules becoming imbedded in the gap electrodes. Gas clean-up means that as the ages, it no longer operates at the pressure for which it was designed. Longer recovery times result, causing echo signals from nearby targets to be lost. This may be an important consideration in short-range radar. Sputtering of the material from the electrodes is also a common occurrence TR tubes, especially those with keep-alive electrodes. Sputtering causes short circuiting of the keep-alive and detuning of the resonant circuit. The end of life of a TR tu is determined more by the amount of leakage power which it allows to pass than by physical destruction or wear. A TR tu is considered unsatisfactory when it no longer affords receiv protection. Several hundred hours of life is considered typi of conventional TR tubes.

Both the keep-alive and the water-vapor filling in TR tub reduce the useful life. If rapid TR breakdown and rapid reco times were not necessary, simple and reliable TR tubes of lon life could be constructed using pur noble gases.

the arc loss can be sufficient to melt the input window. The arc loss in tubes filled with argon may be 0.1 db or less. On reception, the TR tube introduces an insertion loss of about ½ to 1 db, which attenuates the echo signal. The arc loss, insertion loss, and the keep-alive noise reduce the sensitivity of the radar and should be taken into account in any accurate prediction of radar performance.

The ATR tube has less stringent demands placed upon it than does the TR tube. Therefore it is usually simpler. An ATR might use a pure noble gas such as argon since recovery time generally is not of importance. Furthermore, priming agents such as the keep-alive are not needed. The absence of both chemically active gases and a keep-alive results in ATR tubes having longer lives than TR tubes.

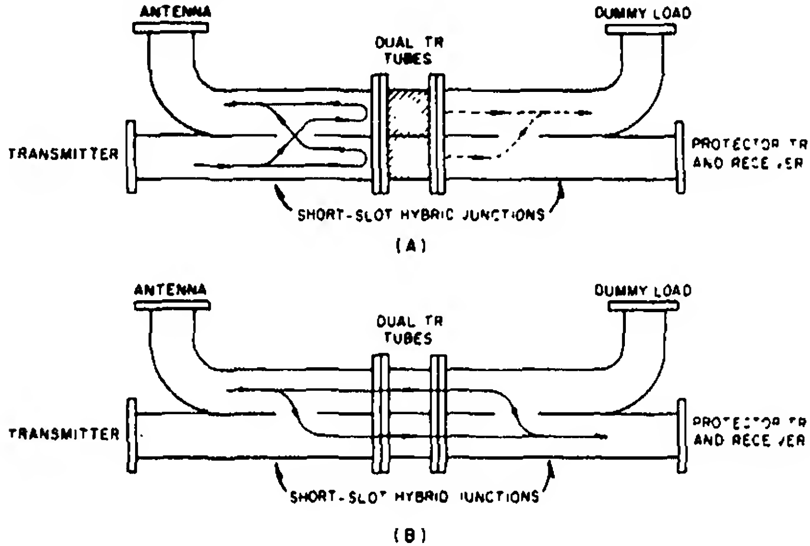


FIGURE 5 Balanced duplexer using dual TR tubes and two short-slot hybrid junctions. (a) Transmit condition; (b) receive condition.

Balanced Duplexer.

There are several circuit arrangements of TR and ATR tubes for switching and for receiver protection in addition to the branched duplexer. The branched duplexer is the simplest configuration, but is is non-inherently broadband. A more broadband arrangement is the balanced duplexer (Fig. 6). In principle, its bandwidth is limited only by that of the waveguide. Balanced duplexers employ a hybrid junction of some sort. (A

antenna arm as shown. The short-slot hybrid has the p
that each time the energy passes through the slot in e
direction, its phase is advanced 90°. Therefore the e
must travel as indicated by the solid lines. Any ener
leaks through the TR tubes (shown by the dashed lines)
directed to the arm with the matched dummy load and no
receiver. In additon to the attenuation provided by t
tubes, the hybrid junctions provide an additional 20 t
of isolation.

On reception the TR tubes are unfired and the echo
pass through the duplexer and into the receiver as sho
Figure 5b. The power splits equally at the first junc
because of the 90° phase advance introduced on passing
the slot, the energy recombines in the receiving arm a
the dummy-load arm.

An example of a balanced duplexer is shown in Figu
This particular X-band unit operates over the frequenc
from 8,490 to 9,578 Mc and is capable of withstanding
peak power. The insertion loss on reception (duplexer
1.2 db.

A low-power TR tube (which might also be a diode l
called a receiver protector, is often placed between t
balanced duplexer and the receiver to safeguard the re
against

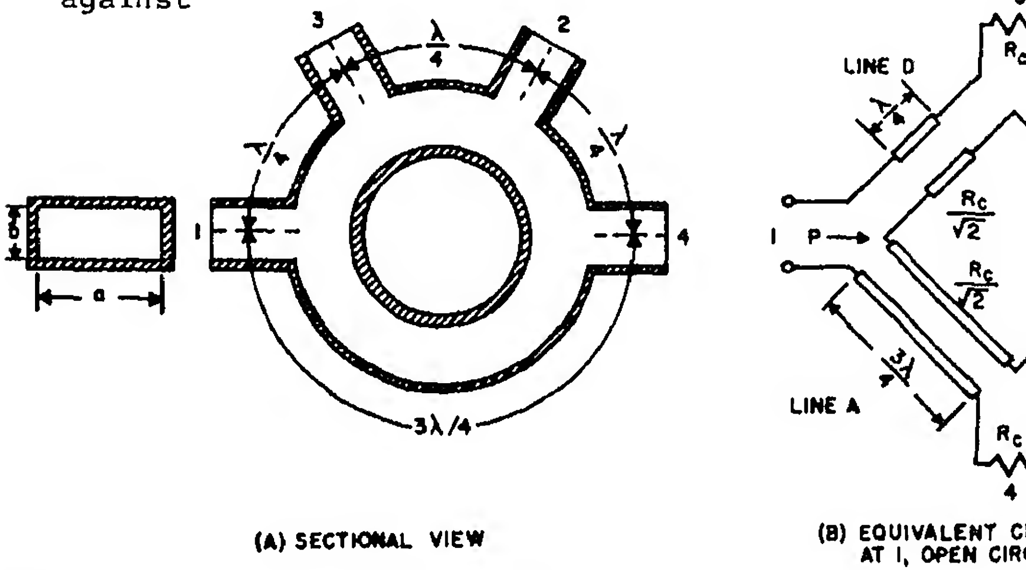
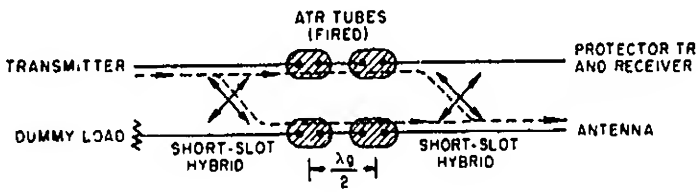


FIGURE 6 Waveguide hybrid junction of one and one half-wav
type

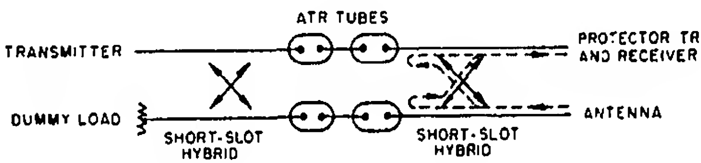
may be designed to fire at low power levels and to provide the optimum receiver protection. In this manner each tube is designed to perform its single function in an optimum manner instead of compromising the design by combining the two functions of switching and protection in a single tube.

Another form of balanced duplexer uses four ATR tubes and two hybrid junctions (Fig. 7). The ATR tubes reflect the echo signal into the receiver in this duplexer arrangement as contrasted with the balanced duplexer of Figure 5, where the TR tubes reflected the transmitter power into the antenna. During transmission (Figure 7a), the ATR tubes fire and high power is allowed to pass to the antenna. Dashed lines show the flow of power. During reception (Figure 7b), the ATR tubes present a high impedance, which results in the echo signal power being reflected to the receiver. A protector TR tube ahead of the receiver prevents excess signal power from entering the receiver. The ATR type of balanced duplexer has high power-handling capacity that that in Figure 5, but it has less bandwidth.

Duplexer action may also be obtained with two hybrid junctions and a half-wavelength power-sensitive phase shifter, as shown in Figure 8. The power from the transmitter is applied to arm 1, where it divides equally between arms 3 and 4, If the path lengths between the two hybrids are equal, all the power will pass into the antenna arm 7 because of the 90° phase shifts introduced by the hybrid junctions. On reception, the

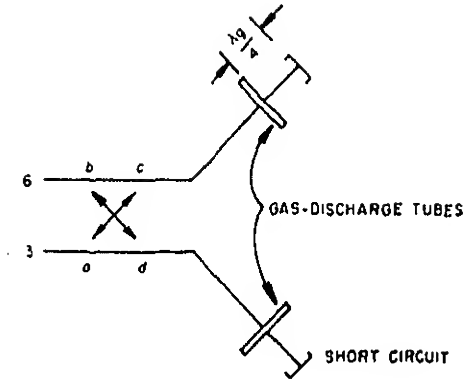


(A)



(B)

URE 7 Blanaced duplexer using ATR tubes. (a) Transmit conditio

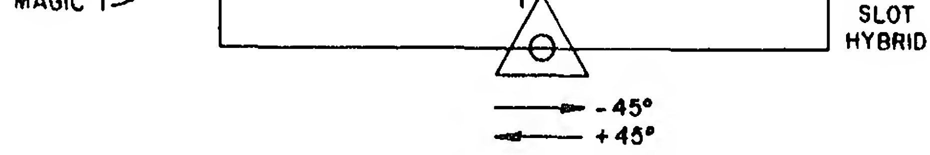


(B)

*FIGURE 8 (a) Principle of the phase-shift duplexer; (b) H
wavelength, power-sensitive phase shifter.*

phase shift in the power-sensitive phase shifter betw
and 3 is increased by half a wavelength. The phase c
power will cause it to enter the receiver arm rather
transmitter arm.

A method of providing a half-wavelength power-sen
phase shifter is shown in Figure 8b. It consists of
hybrid junction and two gas-discharge tubes. Metal s
plates are spaced a quarter wavelength behind the tub
high-power transmitter pulse (from arm 3) enters arm
divided equally between arms c and d. The gas-discha
break down, and the power is reflected and appears in
be delivered to arm 6 of Figure 8a). On reception,
echo signal enters arm b. The echo power is too weak
the gas-discharge tubes; consequently, the low-power
travels a quarter wave farther before being reflecte
metal short. Thus the received signal travels a tot
a wavelength more than the high-power transmitter pu
has been claimed that the power-handling capacity of
shift duplexer is twice that of a balanced duplexer
same components.



RE 9 Nonreciprocal differential phase-shift ferrite duplexer.

Ferrite Duplexers

There are a number of methods by which ferrite devices such as faraday rotators, isolators, circulators, and phase shifters may be used in duplexer applications. The phase-shift duplexer described in Figure 8 may be used with a ferrite phase shifter as well as with a gas-discharge device. The nonreciprocal differential phase-shift ferrite duplexer is shown in Figure 9. The transmitter power enters the H-plane arm of a magic T and splits equally into the two collinear arms. In one arm the phase is advanced 45° by the ferrite phase shifter, and in the other, it is retarded 45°. The two signals then enter a short-slot hybrid juncton, and because the phase relationships are proper, they recombine in the antenna arm.

On reception, the signal power is divided equally by the short-slot hybrid junction. The phase shifts introduced by the ferrites are now reversed because propagation in the nonreciprocal phase shifter is in the opposite direction; that is, the phase of the upper arm is retarded 45°, and in the lower arm it is advanced 45°. This phase differential plus the 90° phase advance introduced in the lower arm by the short-slot hybrid results in a total phase difference of 180° between the signals in the two arms. This is the proper phase relationship if the two signals entering the collinear arms of the magic T are to recombine in the E-plane (receiver) arm with no energy entering the H-plane (transmitter) arm. A protector TR may be inserted in the receiver arm as protection against transmitter leakage, reflected power from the antenna during transmission, and radiation from nearby radars during the receiving period.

Ferrite duplexers have the advantage of shorter recovery times and longer life than gas-discharge duplexers. They are relatively broadband. However, they are usually of larger size and weight and require magnetic fields for their operation. Another form of all solid-state duplexer consists of a three-port ferrite circular with a diode limiter ahead of the receiver.

"shutter tube" in which one or more cones are short
solenoid-activated device.

LESSON TOPIC LEARNING OBJECTIVES:

11.4.1 Given a list of statements concerning the shape and be characteristics of a parabolic-reflector, select the correct statement(s).

11.4.2 Given a list of statements concerning the shape and be characteristics of a cosecant-squared reflector, selec correct statement(s).

11.4.3 Given a list of statements concerning the reasons for a cosecant-squared reflector, select the correct statement(s).

11.4.4 Given a list of definitions, select the correct defin for antenna reciprocity.

11.4.5 Given a list of definitions, select the correct defin for an isotropic antenna.

11.4.6 Given a list of definitions, select the correct defin for directive gain.

11.4.7 Given a list of definitions, select the correct defin for power gain.

11.4.8 Given a list of statements concerning the electrical characteristics of an array antenna select the correc statement(s).

11.4.9 Given a list of statements, select the correct statem which describe the beam characteristics that determin

a. bearing/azimuth resolution.
b. altitude resolution.

11.4.10 From a table of statements, match the statements give lobe configurations with their applications.

11.4.15 Given a list of statements, match the two types
radome construction to their comparative advanta

STUDY ASSIGNMENT

Read:

1. Skolnik, M.L. Introduction to Radar Systems, McG
1962, Ch 7, pp. 223-250, Ch 8, pp 278-318.

2. Reintjes and Coate, Principles of Radar, McGraw-
Ch 13, pp. 937-958.

COMPLETE: Student Activity Guide 11.4.1S

STUDY QUESTIONS: None

What is an isotropic antenna?

When can directive gain equal power gain?

The effective aperture of a radar antenna is described as a measure of?

What geometric contour is the most widely used in the construction of radar antenna reflectors?

What is the reason for using a parabolic reflector?

List the three factors whose product determines the overall efficiency of a radar antenna.

What two main factors determine the gain of a parabolic reflector?

squared pattern.

11. What is the effect on antenna gain when a paraboli
is changed to operate as a cosecant-squared refle

12. List two methods of generating an asymmetrical (fa
pattern from a parabolic reflector.

13. Describe the geometrical configuration of a linea
antenna.

14. Describe the geometrical configuration of a plana
antenna.

15. What type of antenna pattern will a linear array
present when the phase relationships of the indiv
are such that it causes the primary pattern to la
perpendicular to the array?

18. In what plane is the flare of the feed horn made to feed th
truncated paraboloid?

19. What are the three basic feed methods of parasitic phased arrays?

20. What are the two types of radome construction?

ne requirements of the antenna and its feed system are basical
ne same for a radar as for communication systems, although it
ppear quite different, due mainly to the frequencies used in r

ne purpose for which the antenna is to be used will also deter
ne design of the array. For instance, a fire-control system
equires that the energy be radiated in a very narrow pattern,
ther radars may require a wide beam, at least in one of its
imensions.

nother consideration in radar antenna design is the fact that
ntenna must be used for reception of the echo signal shortly a
ne transmitter has fired.

ne same antenna is used for both transmit and receive function

EFERENCES:

. SKOLNICK, M.L. Introduction to Radar Systems, McGraw-Hill 1
Ch 7, pp. 223-250, Ch 8, pp. 278-318.

. REINTJES and COATE, Principles of Radar, McGraw-Hill 1952,
Ch 13, pp. 937-958.

NFORMATION

ADAR ANTENNA SYSTEMS

. Types of Antennas

1. Parabolic Reflectors - Virtually all airborne antenna
ystems use a parabolidal surface as a reflector to shape the
eam. The full-parabola type will create a beam that is conica
r pencil-shaped, and the parabola may be modified in one or mo
f its dimensions to achieve the desired radiation pattern.

a. Figure 1 illustrates the usefulness of a parabolic
surface as a reflector. If a beam of parallel wave
is incident upon the curved surface, the rays will
reflected and made to cross at a point called the

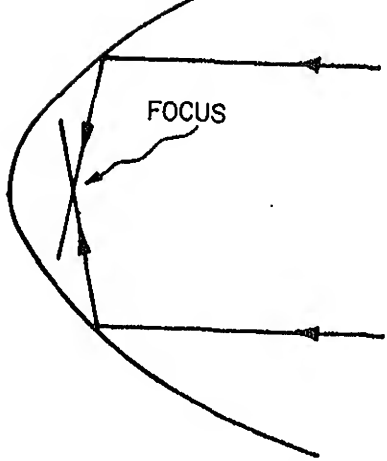


Figure 1

c. The feedhorn of the antenna system is normally placed slightly outside the focal point, in order to aid in the sharpening of the radiated pattern. The feedhorn will be designed and placed in such a manner that it will illuminate the entire reflector, yet not cause a great amount of energy to miss the dish entirely and create back-lobes (called Spillover).

2. Orange peel reflectors (Figure 2)

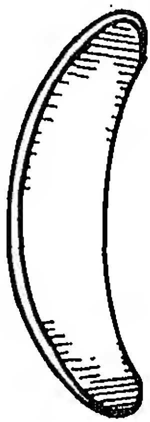


Figure 2

c. The feedhorn for this type system would also be specially shaped, since the dish must be illumina before. The end of the waveguide is flared to co the radiated beamwidth of the feedhorn, with the flare producing a narrower beam. Therefore, the narrower dimension of the feedhorn will illuminat the long dimension of the reflector, and create t narrow dimension of the radiated beam pattern.

3. Cosecant Squared Reflectors (Figure 3)

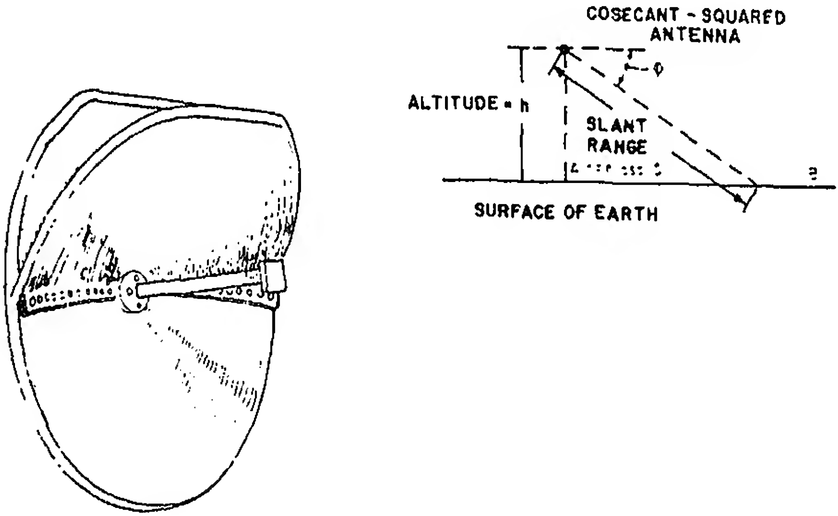
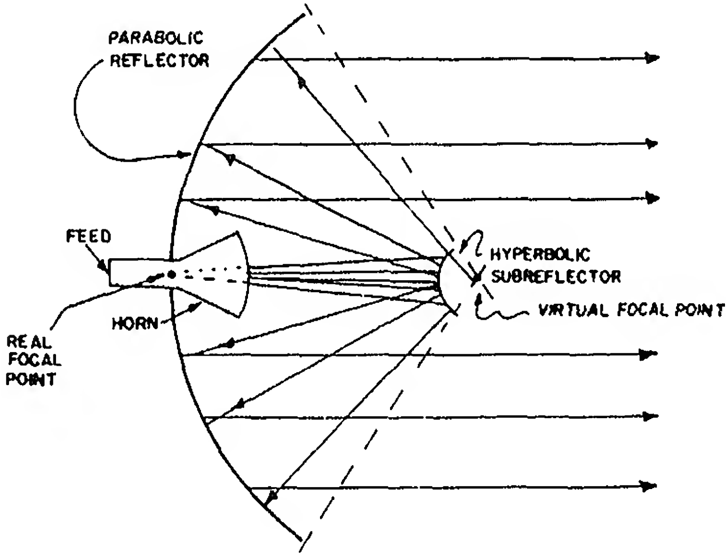


Figure 3

a. The upper portion of the parabola is bent forward cause part of the energy to be radiated downward, additional energy to be added to the beam for dis targets. The field intensity is such that it wil vary as the square of the cosecant of the angle b a horizontal line projecting from the antenna and

4. Cassegrain Antenna (Figure 4)



a. The principles of the Cassegrain Antenna is that i uses two reflector surfaces. The larger (primary) reflector has a parabolic contour while the smalle (secondary) subreflector has a hyperbolic contour.

b. Two focus points are produced. The real focal poi produced by the contour of the hyperbolic subrefle is normally located at the vertex of the parabola. real focal point is where the feed system will be located. The virtual focal point produced by the contour of the parabolic reflector is located beyo the subreflector.

c. Parallel rays of energy reflected from a target ar collected and reflected by the parabolic surface a a convergent beam to the hyperbolic surface where are re-reflected to the real focal point and transferred to the waveguide via the feed system.

B. System Requirements

these requirements.

b. The beamwidth is held to a narrow pattern in
plane, so that azimuth information accuracy
and bearing resolution is not impaired.

2. Height Finding Radars

a. A fan beam is required for height finding op
well as in a search radar, except that altit
resolution must be maintained. A vertically
orange peel is satisfactory for this purpose

b. The antenna is rotated in azimuth as a searc
until a target is detected. At this time, t
is stopped, and the beam is "Nodded" vertica
determine the angle to the target.

3. Fire Control Radars

a. Requires a fan beam for search mode, and a c
for accurate tracking of targets.

b. One method of accomplishing both features wi
antenna is to apply a spoiler to a parabola,
can be moved out of the way when performing
operations.

e. Another method is by off-setting the feedhor
half the beamwidth and rotating the feedhorn
during the Track mode.

receivers and timing systems.

N TOPIC LEARNING OBJECTIVES:

1 Given a block diagram of a typical radar receiver and a list of functions, MATCH the function to the appropriate block.

2 Given statements concerning the function and operation of the local oscillator, SELECT the correct statement(s).

3 Given statements concerning the function and opeation of the mixer, SELECT the correct statement(s).

4 Given statements concerning radar I-F amplifier design considerations, SELECT the correct statement(s).

5 Given statements concerning video amplifier design considerations, SELECT the correct statement(s).

6 Given statements concerning the function and operation of IAGC circuits, SELECT the correct statement(s).

7 Given statements concerning the function and operation of FTC circuits, SELECT the correct statement(s).

8 Given statements concerning the function and operation of STC circuits, SELECT the correct statement(s).

9 Given statements concerning the function and operation of a synchronizer in a radar, SELECT the correct statement(s).

ASSIGNMENT:

ead: 1. Aviation Electronics Technician 1 and C, NAVPERS 10318-D, pp. 198-208.
2. Information Sheet No. 11.5.1I "Radar Receivers."
3. Information Sheet No. 11.5.2I "Synchronizers."

TE: STUDENT ACTIVITY GUIDE 11.5.1S

QUESTIONS: NONE

_____a. accuracy of the afc system.
_____b. sensitivity of the receiver.
_____c. value of the intermediate frequency.
_____d. signal to noise ratio of the receive

2. The minimum usable signal in a radar set is

_____a. ineffective below one milliwatt.
_____b. the minimum signal echo that will ac afc system.
_____c. the signal strength that barely exce to-noise ratio of 1/1.
_____d. the signal strength that barely satu final i-f amp.

3. The mixer in a radar set mixes the

_____a. video and audio portions of the echo
_____b. returning radar energy with the loca energy.
_____c. intermediate-frequency energy with t radar energy.
_____d. crystals in the input of the i-f amp

4. The purpose of the Wallman cascode amplifier

_____a. wide bandpass, with the gain charact pentode and the noise characteristic
_____b. narrow bandpass, high gain, and low input of the i-f amplifier.
_____c. a reference level to determine the s noise level.
_____d. isolation between the input crystals i-f stage.

5. The primary function of the afc system is to

_____a. keep the klystron's frequency consta of transmitter variations.
_____b. keep the intermediate frequency cons less of transmitter's variations.
_____c. keep the transmitter frequency const less of load variations.
_____d. keep the transmitter's frequency con

the frequency.
______d. zero.

The basic function of the timer in a radar system is to

______a. fire the transmitter and start the sweep circuits at the proper time.
______b. start the range marker circuits.
______c. synchronize the blanking and gating circuits.
______d. provide a variable PRT for different ranges.

A radar timer is sometimes referred to as a

______a. stabilizer.
______b. range mark generatro.
______c. synchronizer.
______d. sweep generator.

The three main requirements for a timing system are

______________________, ______________________, and

______________________.

Changing the PRF of a radar does/does not affect the pulse width of the transmitter.

List at least four circuits that might be triggered by the timer.

a. ______________________ c. ______________________

b. ______________________ d. ______________________

1. The energy of a received signal is generally o
amplitude, often a picowatt or less. Conseque
other factors being equal, the efficiency of a
system is dependent upon the efficiency of the
This means that a relatively small increase in
efficiency may extend the maximum range of a r
greater extent than a large increase in transm
power.

2. For example, suppose we increase the sensitivi
receiver by 3 db: This means that a signal ec
be half as large as before, and still be detec
usable return. In order to realize the same r
by increasing transmitter power, it would requ
increase of four times the original output pow

3. In general, the amplifiers in use today have t
ability to detect and amplify these minute ret
cannot distinguish between signal and noise.
problem then, is to reduce the noise seen by t
amplifier to a level that will cause the signa
appear large by comparison. Since atmospher r
always be present, there is little that can be
eliminate it. The major area of research ther
about reducing the internally-generated noise.

B. <u>Circuitry requirements</u>

1. The receiver of a radar system is made up of
separate circuits. These include the mixer,
mediate-frequency amplifiers, detector, and v
amplifier.

2. There are in addition to the basic requiremen
several circuit-improving devices, such as r-
amplifiers to increase the signal's amplitude
applying it to the receiver, and automatic fr
controlling circuits to ensure that the recei
always tuned properly.

REFERENCE - NAVPERS 10318-D Aviation Electronics Tech
1 & C

. Because of the high internal noise generated by tubes at very high frequencies, it is impractical to amplify signals at the frequencies generated by the magnetron. Since the first stage of amplification of a receiver will set the signal-to-noise ratio, r-f energy in the "S" band and above is generally converted to a lower intermediate frequency before amplification takes place. So, when the energy has been reflected from a target and returned back down a waveguide, it is channeled to a crystal, or pair of crystals, reaching this point at the same time as energy from a local oscillator, much the same as in an ordinary superhet radio. The local oscillator signal is usually either 30 MHz above or below the incoming r-f signal, so that when the two mix in the crystals, the 30 MHz signal will be the proper frequency to be amplified by the intermediate-frequency amplifiers. 30 MHz has been selected as a compromise to obtain high gain and a wide bandwidth at an optimum signal-to-noise ratio.

. Of course, when the transmitter emitted its high-power energy in the beginning, some means had to be employed to prevent this high power from entering the receiver and blocking the amplifiers and possibly burning out the crystals. This is where the duplexer is employed. When the transmitter fires, the TR tube ionizes, the ATR tube ionizes, and the energy traveling down the waveguide sees nothing but a smooth wall until it is emitted from the antenna. Then, after the transmitter is no longer energized, the TR tube and ATR tube deionize and, as the energy returns, it sees a low-impedance path to the receiver crystals. The ATR tube serves to reflect a high-impedance block at the entrance of the receiver channel to prevent the returning energy from traveling on down the waveguide and being expended in the magnetron.

. The balanced mixer, sometimes called the "Magic Tee" mixer, plays a very important part in improving the receiver operation. A balanced mixer has the ability, through its design, to eliminate the local oscillator noise. This is actually accomplished in the load (output) of the mixer. The phase relationship of the r-f energy from the local oscillator is such that resultant voltages of local oscillator and local oscillator noise

the grid of the i-f amplifiers and in turn to
second detector, the video amplifiers, and CR

B. I-F amplifiers

1. The first stage of the i-f strip is the deter
factor of the signal-to-noise relationship, b
after the signal is amplified past the first
the addition of minute noise will have minimu
therefore, special consideration must be give
first stage.

2. Triodes are preferred over pentodes where low
important; however, the triode has other diff
caused primarily by the feedback through the
grid capacity. If the load resistance of the
were made large enough to provide useful ampl
the interelectrode feedback would cause the t
oscillate. The circuit design of the first-s
amplifier is concerned with the neutralizatio
feedback to provide stable operation, yet pro
ficient gain. There are three basic methods
a triode in a circuit, depending upon whether
cathode, grid, or plate is grounded. When us
tubes in each of the three ground configurati
are nine possible conbinations. The best of
combinations is obtained with a grounded-cath
triode, followed by a grounded-grid triode, a
tion known as a cascode amplifier. The groun
second stage loads the first stage so that th
stage has a gain of unity and neutralization
required. The second triode is necessary in
achieve gain. By operating this second stage
grounded-grid configuration, it provides its
to-output isolation. Special cascode amplifi
been developed which provide for the degenera
noise through a band-reject feedback filter.
cascode amplifier provides the stability and
pentode and the low noise figure of a triode

3. Let us next discuss the linear, conventional
amplifier. Actually, this amplifier, other t
wide-bandpass, is not much different from the
ventional i-f amplifier in a radio receiver.
course, there are more stages, because greate

o at least two of the i-f stages after the first tage. This is necessary to have enough control to educe the gain of large signals. Controlling the gain f the i-f amplifiers will vary their selectivity. If he receiver gain is adjusted sufficiently high to bserve distant targets, serious overloading, with ccompanying loss of discrimination, will result for earby targets in the sea-clutter area. On the other and, if the receiver gain is adjusted for best results n the sea-clutter area, distand targents may not be isible. The STC (sensitivity time control) circuit utomatically reduces the gain of the receiver to a uitable value after the transmitted pulse for a period f time. This reduction in gain decays at an RC rate, ncreasing the gain for more distant targets.

nother method of improving the action of the i-f mplifier is "Instantaneous Automatic Gain Control" IAGC). Its action is to reduce the gain of the i-f mplifier by applying a bias voltage to the grids of he i-f amplifiers. The reduction in the i-f signal ccurs almost instantly with the reception of a large ignal, except for a very small delay introduced by a esistor and capacitor put in for this purpose, which s necessary for optimum operation against sea return. hus, each received signal block is reduced sharply nd effectively narrowed by the automatic back-bias ircuit. This reduces signal smearing, particularly on ea-clutter, which consists of signal blocks that lluminate a large area on the screen. Although the esired signal is also suppressed, its recurrence at he same instant and at the same spot on the indicator creen for each scan causes it to have an average llumination which is constant and reasonably bright. he undesired signals, such as sea return or jamming, re continually varying in nature and do not occur at he same points on the sweep for each scan. Consequently, the average illumination and average signal trength for such an area are reduced, while the small arget stands out.

AGC action is applied, usually, to the last half of he i-f strip, with each i-f stage having its own IAGC ircuit. Since this action may not be desired at all imes, some means of switching the circuit in and out

2. If the RC time of the detector were made long,
the maximum amount of signal out, the trailing
the signal would be stretched out, producing a
called Time Base Distortion. This results in
of range resolution and possibly the loss of s
targets in the trailing edge of a larger targe
time were made short to overcome this, the ave
put of the detector would be low, reducing its
efficiency.

D. Video circuits

1. The video circuits of a radar receiver should
bandwidth of from 20 Hz to 5 MHz. This is so
sharp loading and trailing edges as well as th
top portion of the returned echo may be amplif
equally. The returned echo will always have a
mental frequency equal to the fundamental of t
mitted pulse. Radar returns from very large t
such as land masses, would have a very long ti
and therefore a low fundamental frequency comp
The receiver video amplifiers should be able t
all target returns equally.

2. In the video circuit, there is a special circu
is used to assist the operator in separating t
(short time base) targets from the large (long
base) targets, called the "fast-time constant
The FTC circuit is a short-time constant RC ne
the input of the first video amplifier. When
block of video is sent through the FTC circuit
leading edge would cause an output because of
short time constant. A signal on the display
large one, because only the leading edge of ea
them will produce an indication.

E. Automatic Frequency Control (AFC)

1. In any superheterodyne receiver, it is desirab
maintain the local oscillator one i-f away fro
received signal. In radar applications, using
received signal as the reference has disadvant
such as:

a. The system is subject to control by spurio

afc channel, using a controlled sampling of the trans-
mitted frequency as the reference, is generally used.
(See figure 1.)

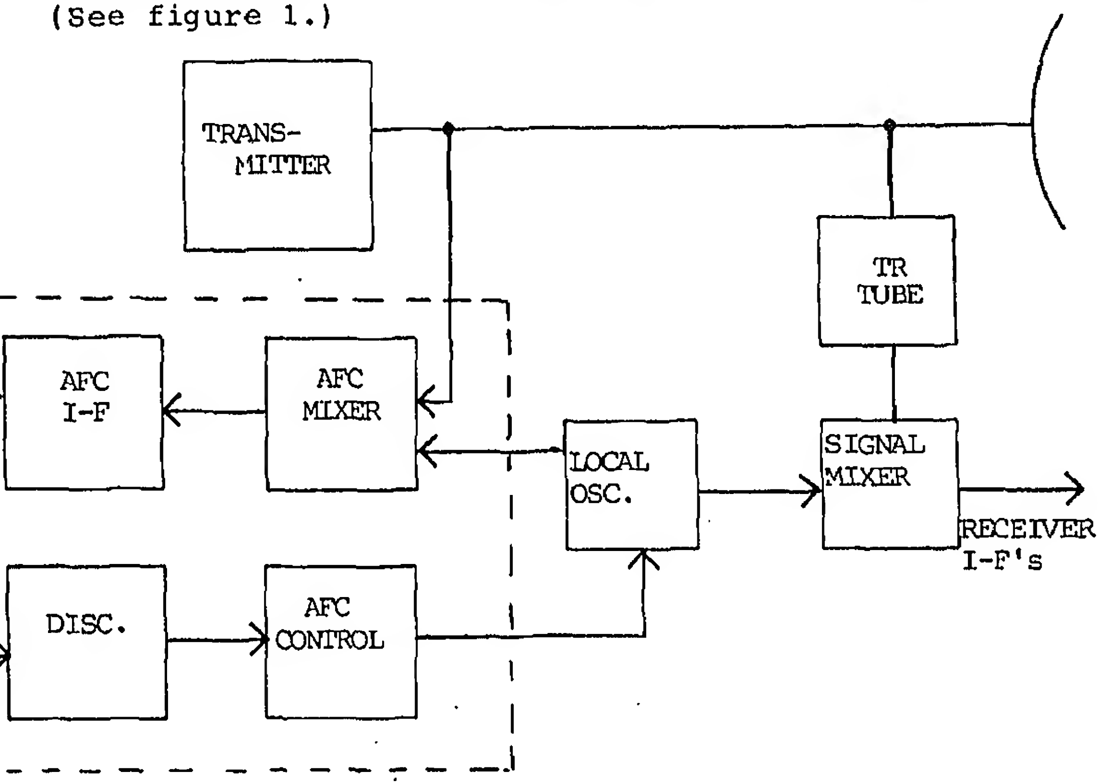


Figure 1

. An automatic frequency control circuit is an arrangemen
for maintaining the constant one-i-f difference betwee
the transmitter and the local oscillator, despite
effects tending to shift these frequencies. The effect
include temperature changes in both the transmitter and
the local oscillator and transmitter load-impedance
changes caused by antenna rotation.

. The pulling of the magnetron, by reactance being couple
back into the oscillator circuit due to antenna rotatio
has been alleviated in some of our more modern radars
by buffering the magnetron from the load with a small
ferrite load isolator as well as ferrite duplexers with
their inherent load isolation.

The following chart shows typical frequency d... to be expected in magnetrons and klystrons:

ENVIRONMENTAL FACTOR	MAXIMUM DIF... FREQUENCY...
Scatter of magnetrons and klystrons received from manufacturer	± 50
Warm-up of radar set	± 1.5
Temperature	± 15
Pressure (0-50,000)	- 2.5
Pushing (± 10% line voltage)	± 5.0
Aging	± 10

5. Tuning errors in the radar receiver degrade t... S/N ratio of the radar. Maximum-range perfor... the radar is thus a function of the tuning ac... the receiver. To obtain the maximum performa... the radar system, the i-f bandwidth must be m... both the receiver pulse and the tuning error ... receiver.

6. To obtain maximum system performance, a compr... between afc performance and bandwidth must be... provide maximum S/N ratio. The static accura... can be realized in the usual radar is depende... accuracy of the reference and the amount of z... frequency gain it is practical to employ in t... feedback loop.

7. The afc system can be broken down into four c... circuits: (Refer to Figure I.)

   a. MIXER: Its function is to compare two fr... and produce the difference frequency as i...

   b. AFC I-F AMPLIFIERS: Amplifies the output... mixer.

   c. DISCRIMINATOR: Functions as the error de... the system, producing a voltage out, the ... of which is proportional to the deviation...

crease the original error voltage to zero. The process is similar in principle to a servomechanism in that there must always be a small error to provide a correction voltage, but the error required may be decreased by increasing the amplification between the discriminator and the klystron.

AFC Mixer

a. A small fraction of the transmitter pulse energy is obtained for the afc mixer through a sampling connection in the line between the transmitter and antenna. An r-f attenuator is inserted between this connection and the mixer. The attenuation is usually produced by a section of waveguide below cutoff. The attenuation in db is proportional to the length, and this length is adjusted to give the required fraction of transmitter power at the mixer. The attenuation value is very large, from 75 to 92 db, in order to reduce the transmitter power, ranging from 35 kw to 2 mw, down to the 1 or 2 mw at the crystal.

b. Output of mixer is difference between transmitter f_o and local oscillator.

I-F Amplifiers (afc)

a. The purpose of the i-f amplifiers in the afc circuits is essentially the same as that of the main-channel i-f amplifiers.

b. The bandwidth characteristics will be determined by the requirements of the discriminator circuit, and are usually slightly wider than the discriminator's control range. This is done for the purpose of varying the discriminator's control point without requiring a complete realignment of the i-f section.

c. AFC i-f amplifiers normally do not require gain control circuits or any special low-noise features of the main-channel i-f amplifiers.

desired zero output when the difference i
is equal to the desired center frequency

b. Correct afc action has this important cha
tic: When the local oscillator frequency
changed, the voltage change in the discri
output must be such as to oppose the loca
oscillator frequency variation.

c. A direct-coupled amplifier can be added t
system between the discriminator and the
stage to increase loop gain.

11. Control circuits

a. The control circuit, which is the final l
afc chain, has the function of converting
voltage from the discriminator into a loc
oscillator frequency correction. Electro
mechanical tuning are available with the
modulated tubes used as radar local oscil
Electronic tuning is usually adequate to
afc requirements.

b. Diode-phantastron afc (hard-tube afc)(Fig

(1) This circuit also uses the drift-in h
theory of operation, with the diode V
the search stopper and the free-runni
phantastron functioning as the slow-s
generator.

(2) If no error is present, the phantastr
will execute a series of sawtooth dow
sweeps separated by moderately long r
periods. If, during one of the sweep
appear at the discriminator output, t
will be stopped as soon as the discri
crossover frequency is passed.

(3) These pulses are coupled to the shunt
detector negative clamper and cause i
velop a negative voltage. As soon as
age across the diode becomes equal to
age on the phantastron control grid,

with a gain of about 50.

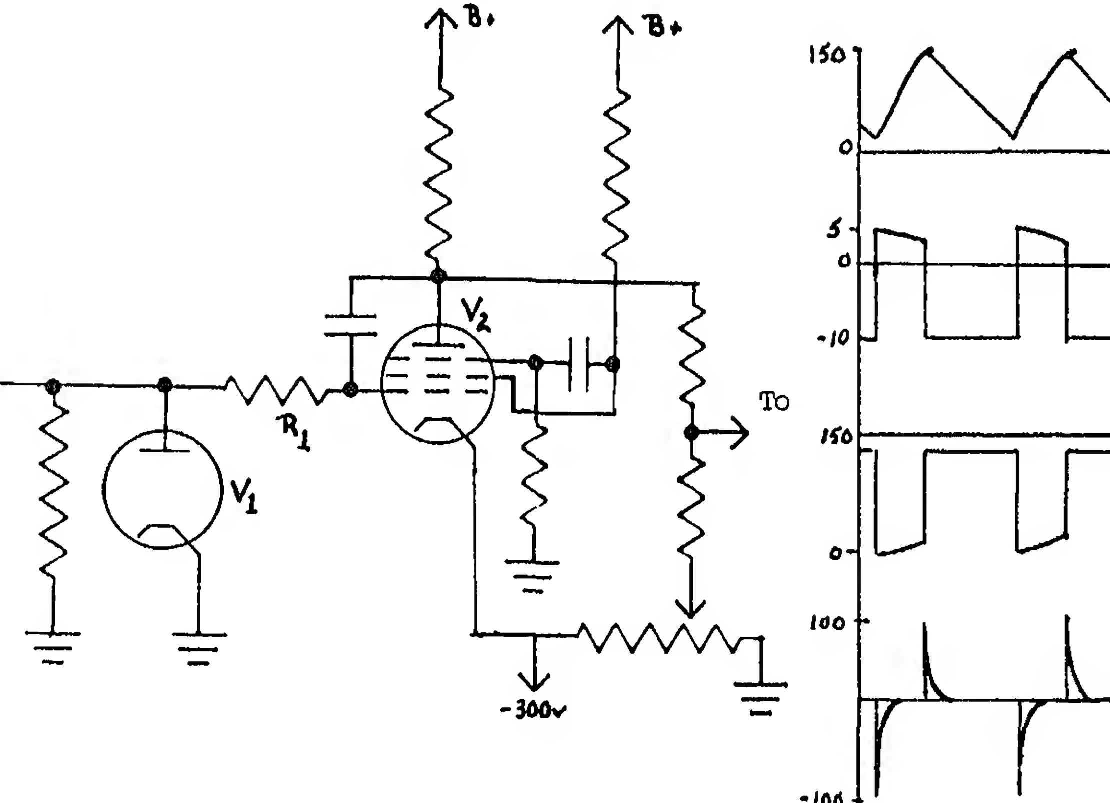


Figure 2

CONCLUSIONS

The efficiency of the radar system is dependent to a large extent upon the performance of the receiver. And the receiver, to perform at its peak efficiency, utilizes special circuits.

The signal is first mixed in the crystals, amplified by a special low-noise, wide-band (Wallman or Cascode) amplifier and then sent on to the rest of the i-f amplifier chain.

The linear i-f amplifier contains a special circuit called a Sensitivity Time Control Circuit which reduces gain at short ranges.

Then there is "Automatic Back-Bias", which is an instanta-

will produce the optimum output.

The basic purpose of the synchronizer in a radar system i that of coordination. In order to accurately determine th range of a target, the firing of the transmitter must occ at a specific time, and the ranging and display circuits must be placed in operation at a precise time in order to measure the elapsed time between transmission and recepti of the echo pulse.

The synchronizer is often referred to as the "timer", and its specific function is to produce the trigger pulse tha starts the transmitter, the sweep circuits, range mark generators, blanking circuits, and the various gating signals that may be required in radar systems.

Timing circuits should meet three basic requirements:

1. Must be free-running (astable) - The timer is the hea of the radar; it must establish the zero reference time and the PRF.

2. Must be stable in frequency (PRF) - The PRF, or its reciprocal, the PRT, must not change between pulses for accurate ranging.

3. Output frequency must be variable - In order to chang PRF to some lower value for longer available range, the timer is usually constructed so that the operator may switch to a submultiple of the basic PRF.

ERENCE - NAVPERS 10318-D Aviation Electronics Technician 1 & C

ORMATION

There are three basic circuits that can meet the above mentioned requirements. They are the sine-wave oscillato single-swing blocking oscillator, and the master trigger multivibrator.

When a blocking oscillator is used as the master oscillat the output pulses may be obtained directly from the oscil lator. When a sine-wave oscillator or a multivibrator is used, pulse-shaping circuits are required to form the necessity timing/trigger pulses.

equally spaced pulses are produced. The repetitio
each series of pulses is determined by the operati
frequency of the master oscillator.

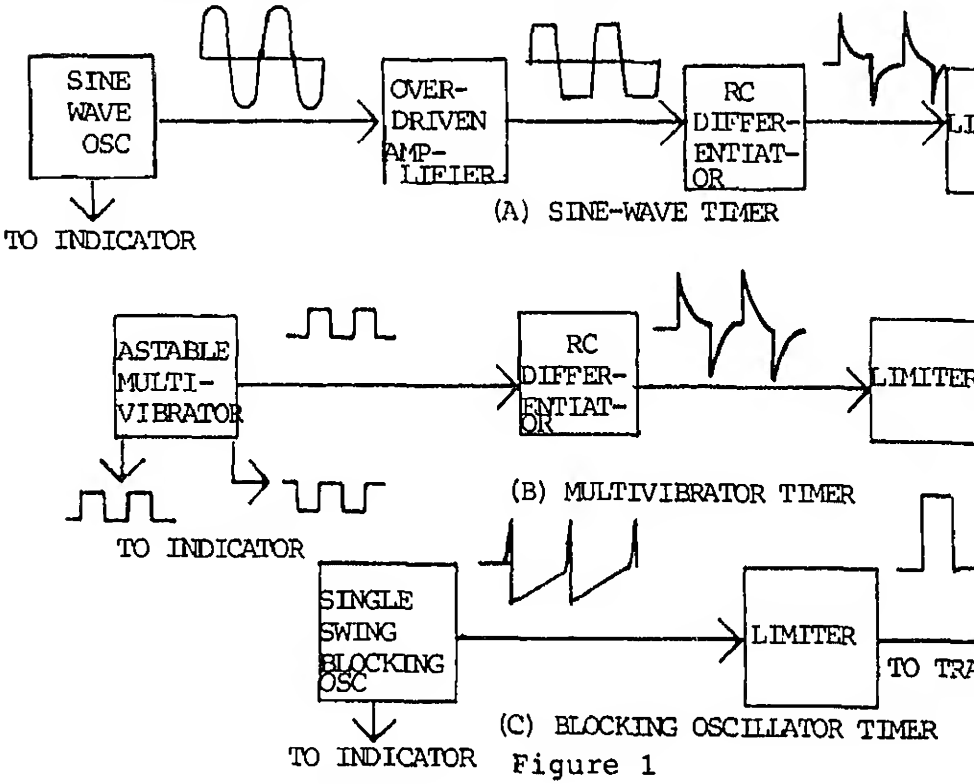
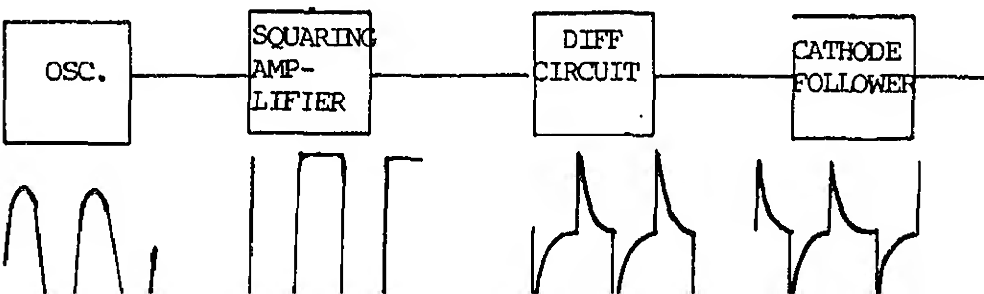


Figure 1

D. Sine-wave oscillator type

1. In figure 2, a sine-wave oscillator is used a
timing device. The oscillator may be a wein-
r-c phase shift type.



4. The cathode follower is used as a convenient means to trigger the basic pulse blocking oscillator and provide isolation between the differentiating circuit and the blocking oscillator. The cathode follower may be biased to limit either the positive or negative portions of the differentiated waveform if desired.

5. The basic pulse blocking oscillator is used to form the desired timing pulse shape. The output frequency may be sub-divided to produce lower PRF's for longer range of operation.

6. The squaring amplifier, differentiating circuit, cathode follower, and basic pulse-blocking oscillator form the basic pulse circuit which determines shape, amplitude, and recurrence time of the timer pulses.

7. One disadvantage of the sine-wave type timing device is that it requires a large number of pulse-shaping circuits to produce the desired output pulse shape. *Therefore, this type is seldom found in modern radar systems.*

Multivibrator Timer

1. Figure 3 is a typical multivibrator timing circuit.

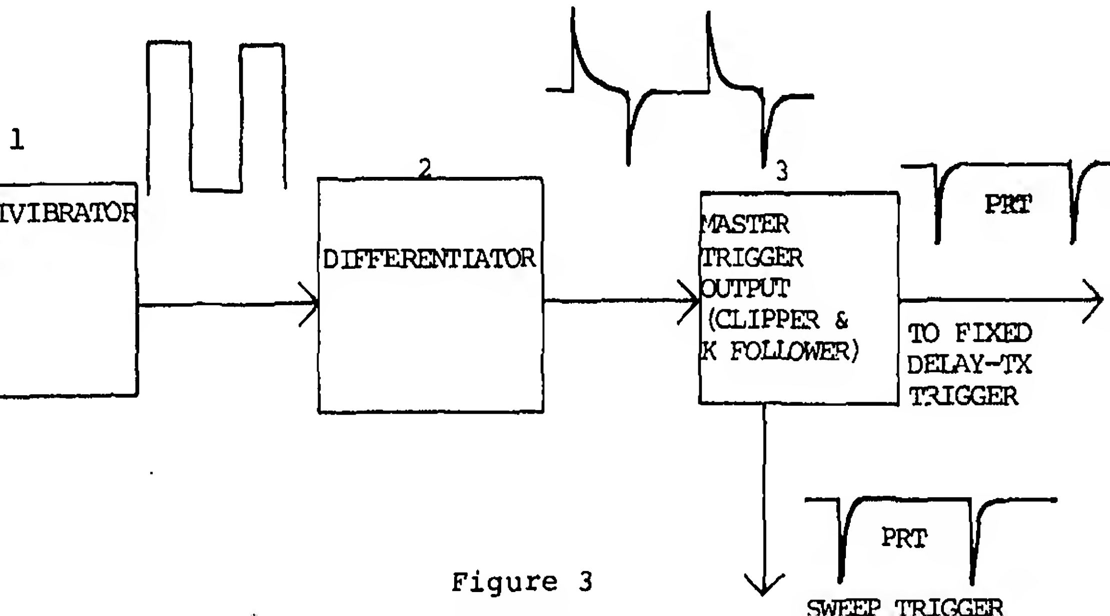


Figure 3

4. Output circuit is usually a cathode foll
limit one half of the waveform.

F. Single Swing Blocking Oscillator Type

1. Figure 4 illustrates a SCBO type timer c
PRF is determined by the R-C network of
circuit.

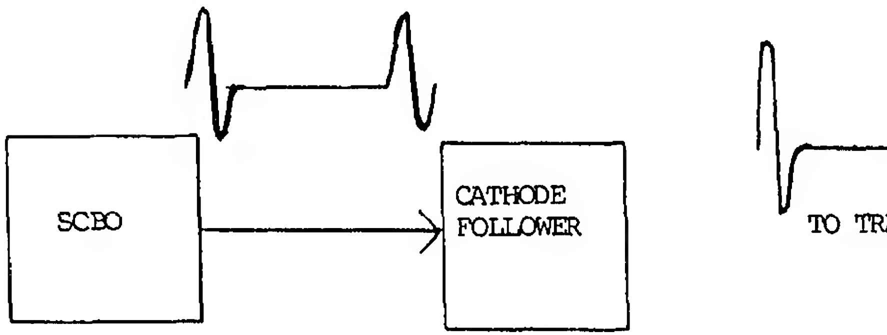


Figure 4

2. When the transmitter is triggered by th
trigger is also supplied to the sweep g
CRT unblanking circuit, and the range m

3. Output waveform may be limited either p
negative by the bias arrangement on the
follower.

4. The advantage of the SCBO type is that
is produced without additional shaping
may be applied directly.

G. An additional type of timer that may be empl
crystal-controlled oscillator. This type i
precise PRF's are required at a particular

Fixed Delay Modulator Trigger - Used with most electromagnetic deflection systems for the purpose of delaying the transmitter's firing until the sweep current waveform has had an opportunity to become stabilized. This delay is usually less than 10 sec.

Range Marker Generator - A precision oscillator that is gated on at the same time as the transmitter is fired. Output is limited, and caused to produce a range mark at the proper time. This circuit is usually made capable of producing several different markers (1 mile, 5 mile, etc.).

Sweep Generator - Produces a linear sawtooth waveform to cause electron beam of CRT to be deflected linearly with elapsed time since firing of the transmitter.

Indicator Unblanking Circuit - Used to unblank the CRT at the desired time in respect to the transmitter's firing. This may be caused to happen prior to, or delayed in respect to, the transmitter trigger, depending upon the tactical situation.

this way, you will be testing yourse

LESSON TOPIC LEARNING IBJECTIVES:

11.6.1 Given statements concerning advantages and of "A" scan to "B", "PPI", and "E" scan, se statement.

11.6.2 Given statements concerning information pre of modulation, advantages of "B" scan prese compared to "A", "PPT", and "E" scan, selec statement.

11.6.3 Given statements concerning information pre of modulation and stabilization used in a " select the correct statement.

11.6.4 Given statements concerning information pre of modulation, and reason for using a secto play, select the correct statement.

11.6.5 Given statements concerning presented, type lation, and reason for using an "E" scan pr select the correct statement.

STUDY ASSIGNMENT:

Read: 1. NAVPERS 10387-A Aviation Fire C Technician 3 & 2, pp. 255-265.

2. NAVTRA 10318-D Aviation Electro Technician 1 & C, pp. 273-313.

COMPLETE: Student Activity Guide 11.6.1S

STUDY QUESTIONS:

1. What are the applications for t types of radar indicators?

2. What type deflection methods do types of radar indicators use?

d. range.

2. In a Type "A" scan, the receiver's output is no
to which component of the indicator?

   a. vertical deflection plates

   b. horizontal deflection plates

   c. cathode

   d. control grid

3. Without auxiliary instruments, the primary disa
a Type "A" scan is that no ________ information

4. In a Type "B" scan, the indicator plots one var
another. Those two variables are:

   a. time vs. range.

   b. time vs. azimuth.

   c. range vs. relative altitude.

   d. range vs, signal intensity.

5. Video data is supplied to the indicator and sup
on the display by ____________ modulation of t
beam.

6. Usually, ________ is presented vertically and
is presented horizontally on a Type "B" scan.

7. In a Type "B" scan, the horizontal location of
indicates:

   a. the range of the target.

   b. the relative altitude of the target.

   c. the relative altitude of the target.

   d. the location of the antenna in respect to t
   boresight.

. the nose of the aircraft.
. the position of the antenna.
. true heading of the aircraft.
. true north.

orth stabilization requires an additional input to the ynchro resolver to reposition the stators as the aircraft aneuvers. This input is from the aircraft's:

. compass system
. radar's slant range.
. true air speed indicator.
. attitude indicator.

n ground stabilization, the origin represents the ________ f the aircraft.

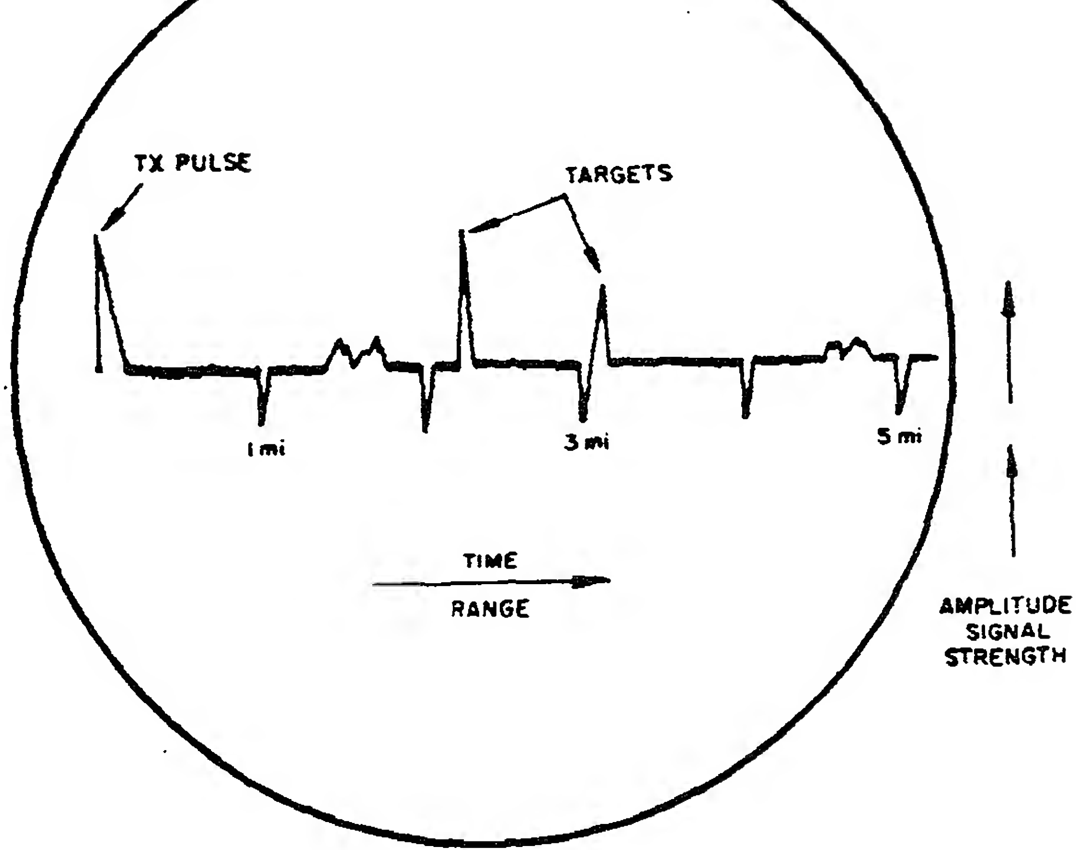
. attitude
. speed
. position
. altitude

n a "PPI" scan, the indicator displays:

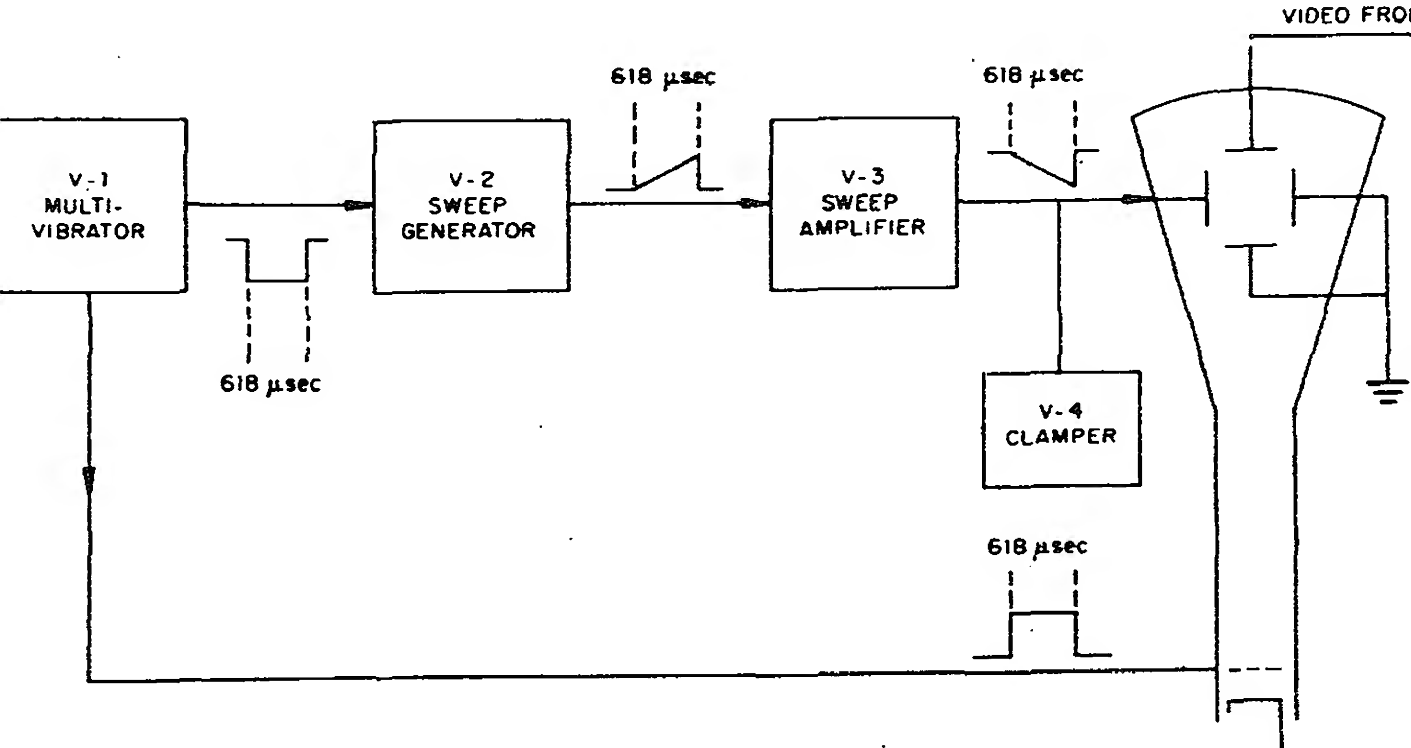
. range and the bearing of the returns.
. range and the elevating of the returns.
. range and relative altitude of the returns.
. azimuth and the elevation of the returns.

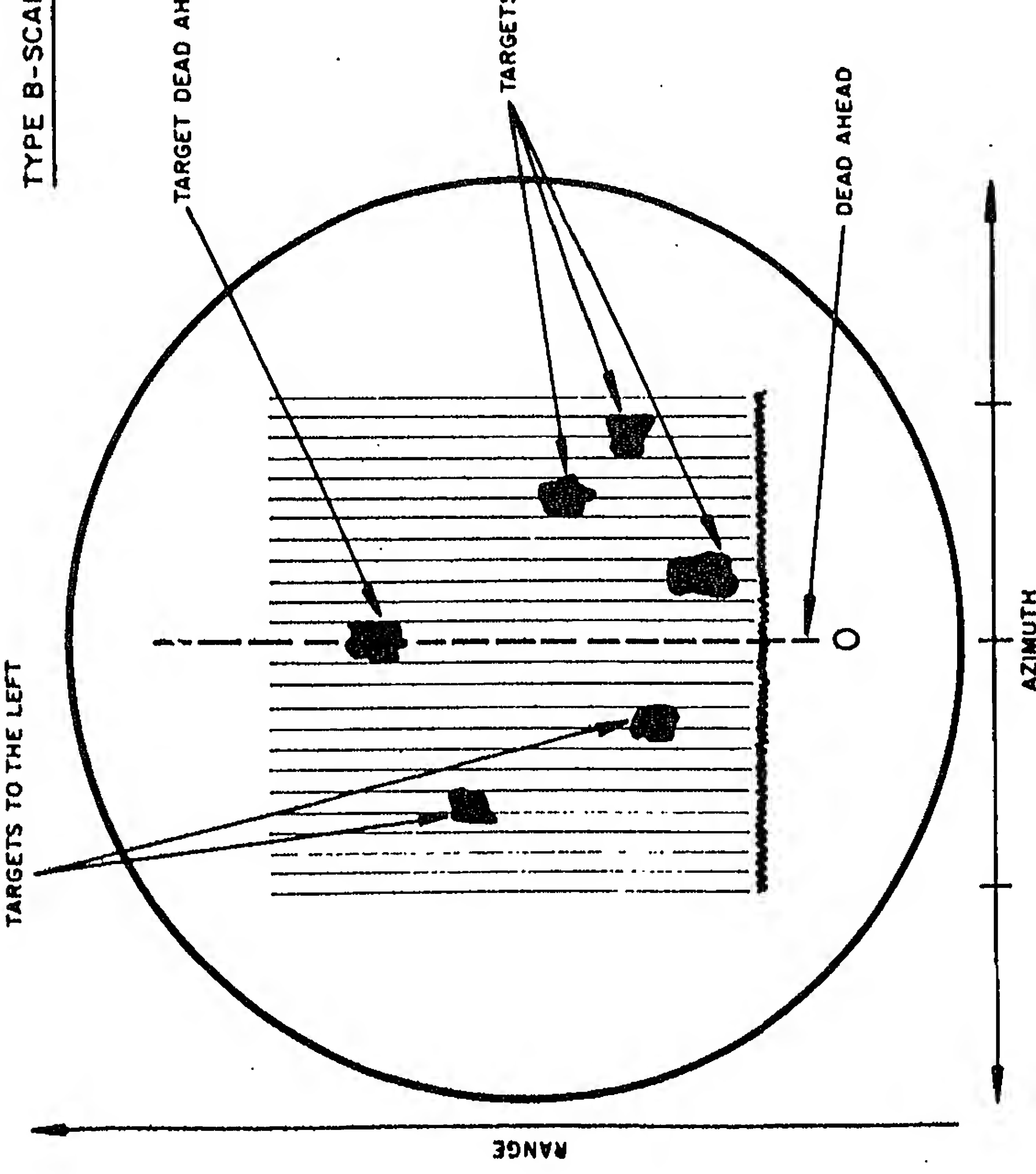
he "E" scan indicator is primarily used with:

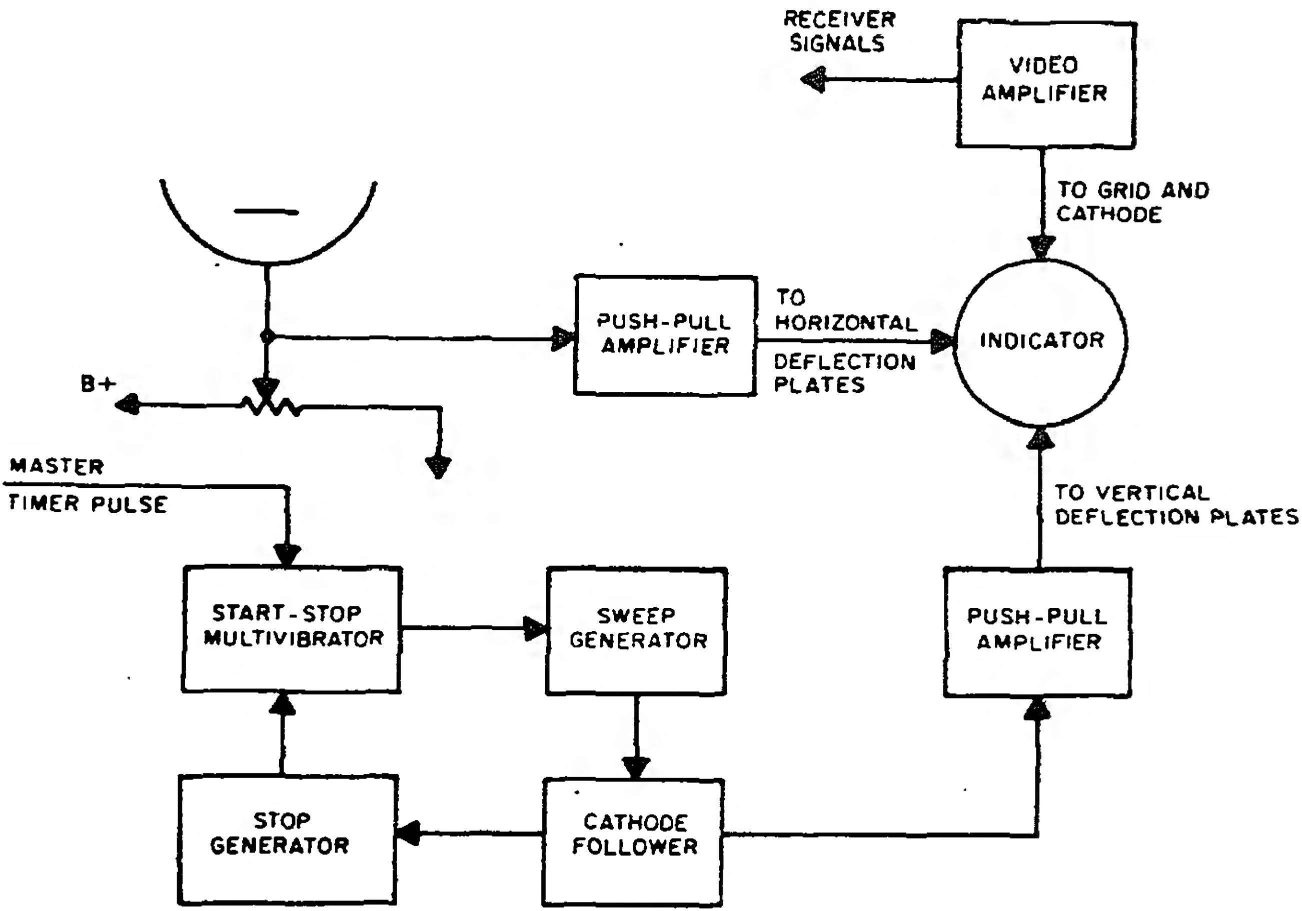
. a bomb director is primarily used with:
. a MTI radar.
. a height finding radar
. a side looking radar.



"A" SCAN PRESENTATION

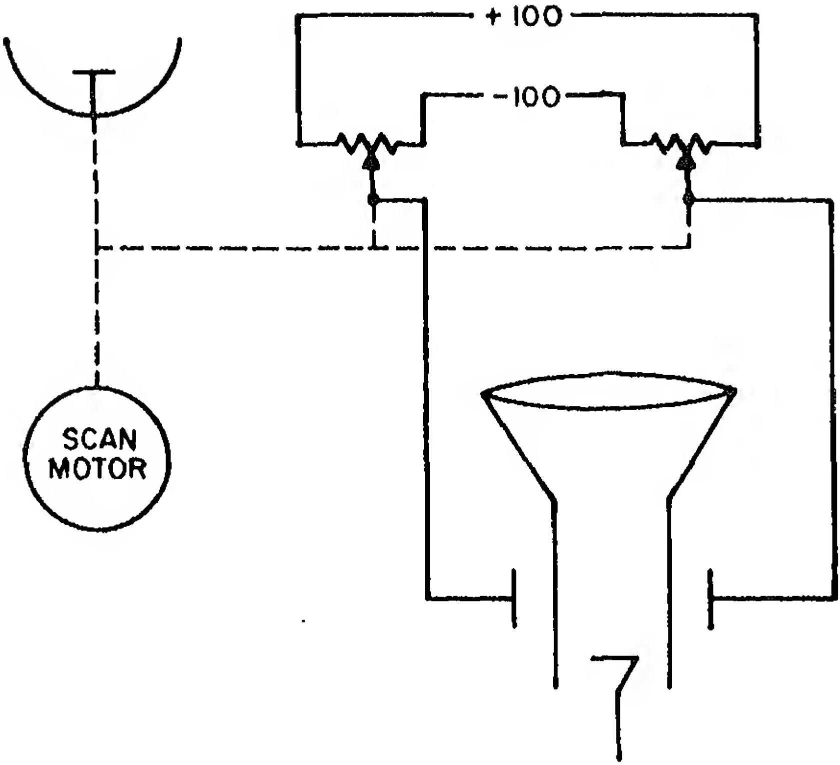

VIDEO FRO
V-1
MULTI-
VIBRATOR
618 µsec
V-2
SWEEP
GENERATOR
618 µsec
V-3
SWEEP
AMPLIFIER
618 µsec
V-4
CLAMPER
618 µsec


TARGETS TO THE LEFT
DEAD AHEAD
AZIMUTH
RANGE

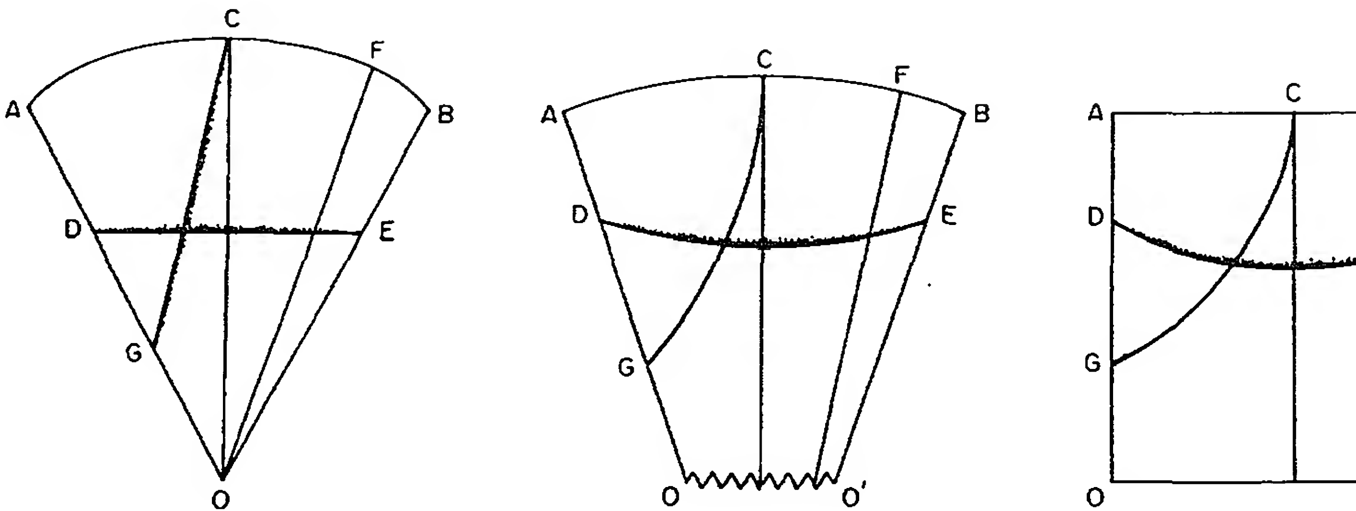


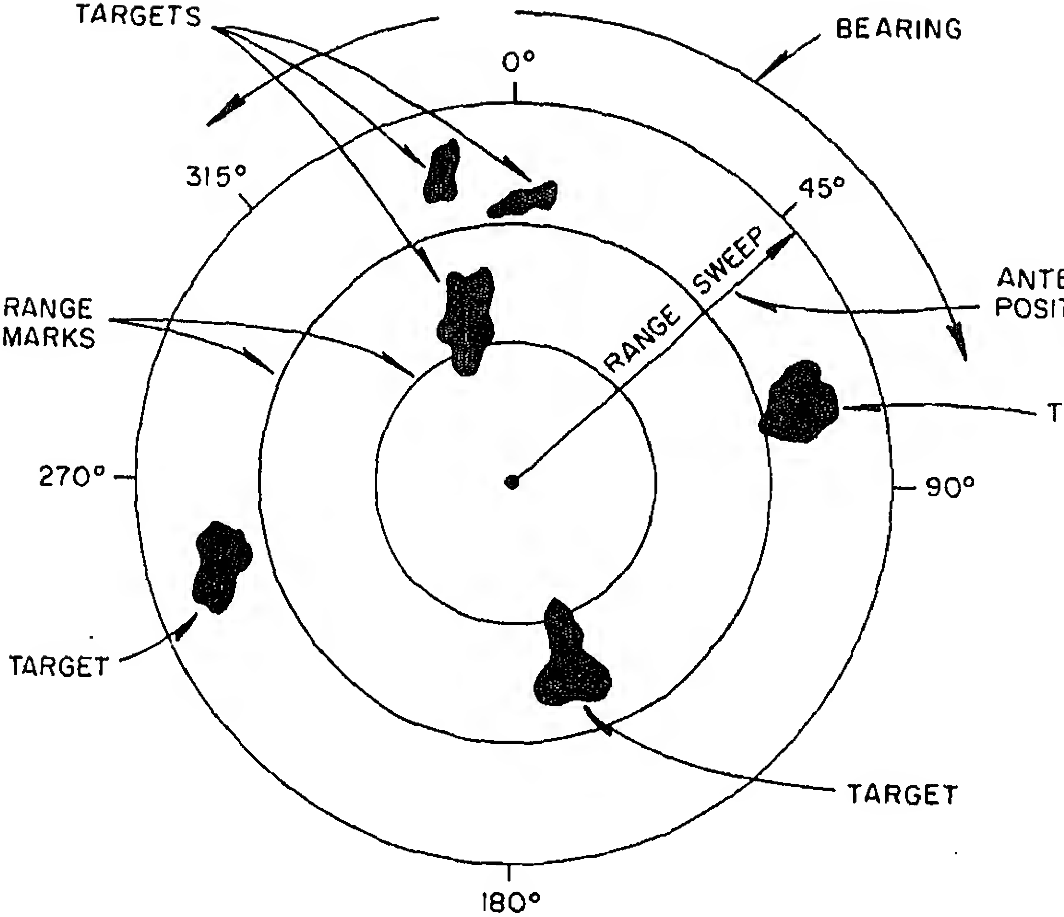
RECEIVER SIGNALS
VIDEO AMPLIFIER
TO GRID AND CATHODE
PUSH-PULL AMPLIFIER
TO HORIZONTAL DEFLECTION PLATES
INDICATOR
B+
MASTER TIMER PULSE
TO VERTICAL DEFLECTION PLATES
START-STOP MULTIVIBRATOR
SWEEP GENERATOR
PUSH-PULL AMPLIFIER
STOP GENERATOR
CATHODE FOLLOWER

FIGURE 4



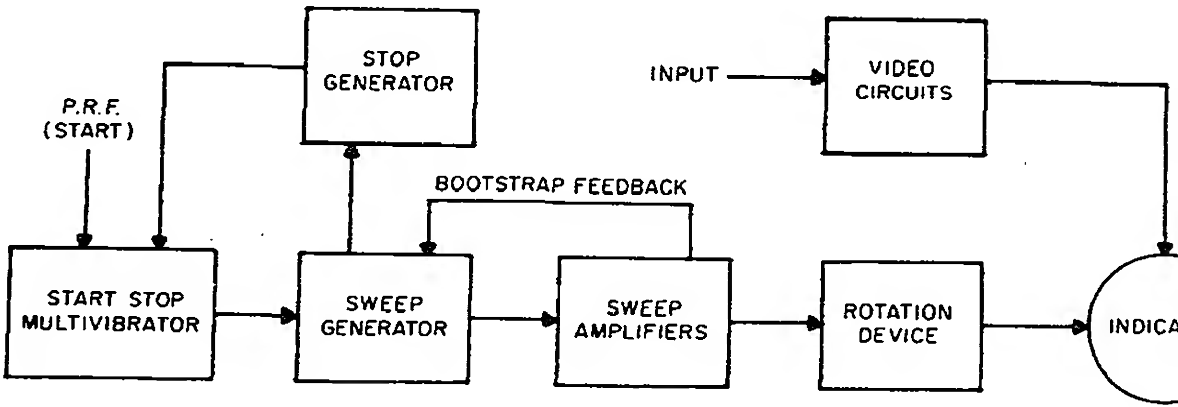
AZIMUTH DEFLECTION POTENTIOMETERS

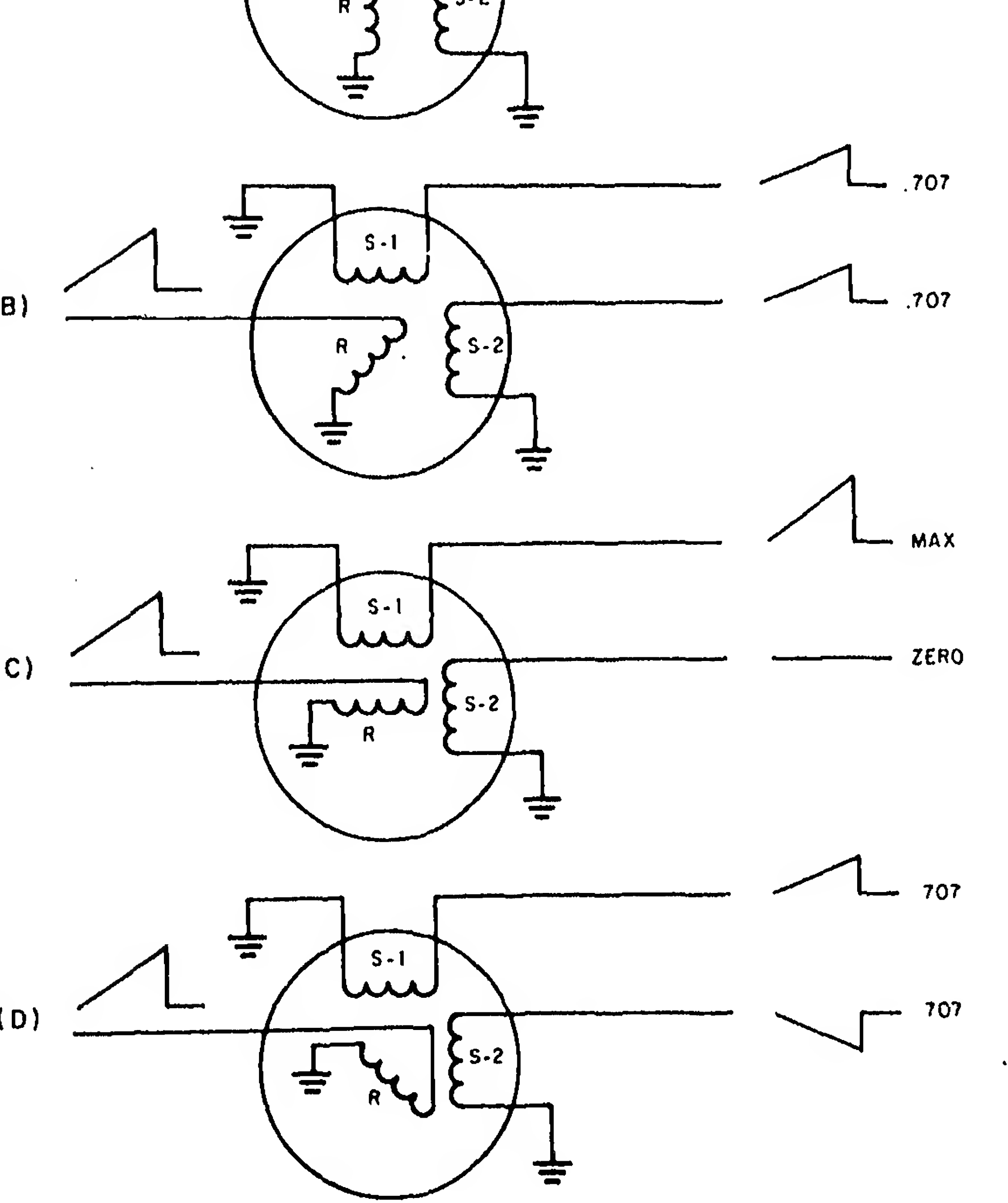

A
C
F
B
D
E
G
O
A
C
F
B
D
E
G
O
O′
A
C
D
G
O



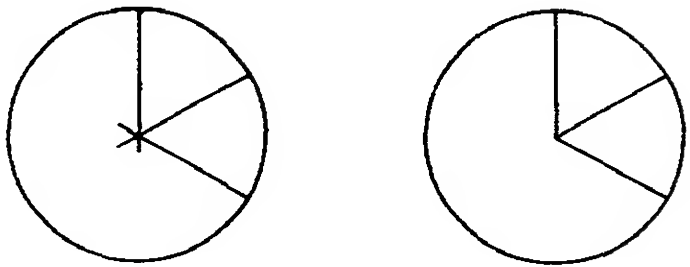
PPI-SCAN PRESENTATION
(Map-like picture)

AQ-2-67

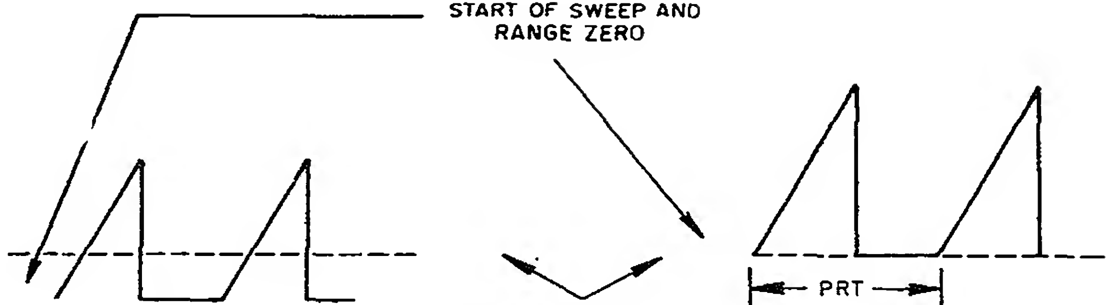

P.R.F.
(START)
START STOP
MULTIVIBRATOR
STOP
GENERATOR
SWEEP
GENERATOR
BOOTSTRAP FEEDBACK
SWEEP
AMPLIFIERS
ROTATION
DEVICE
INPUT
VIDEO
CIRCUITS
INDICA



SYNCHRO RESOLVER FOR ROTATING SWEEP



(A) (B)

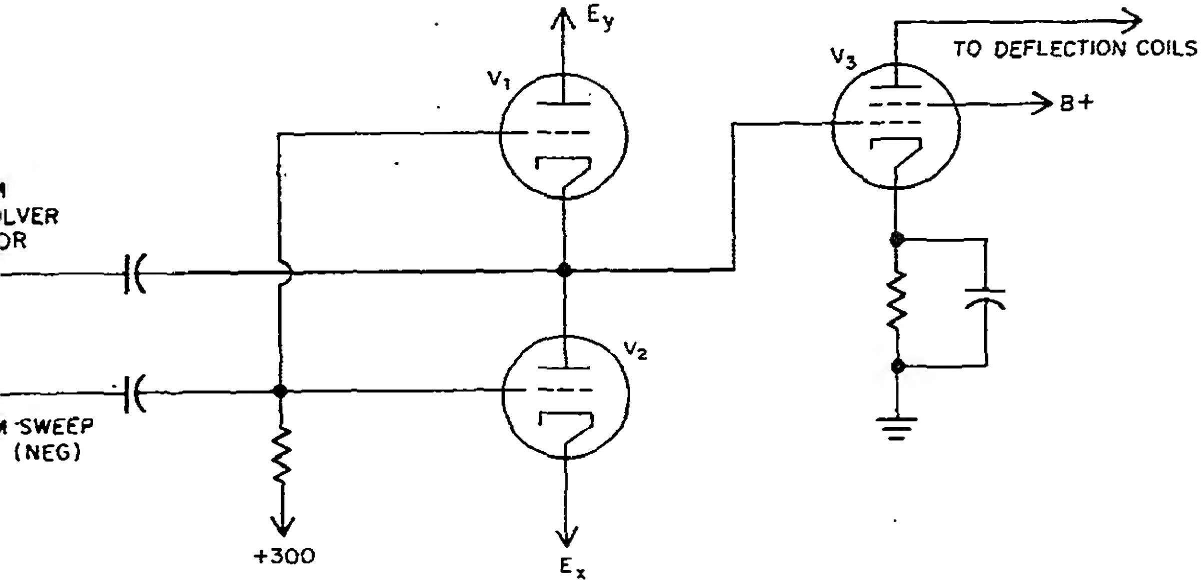


(A)

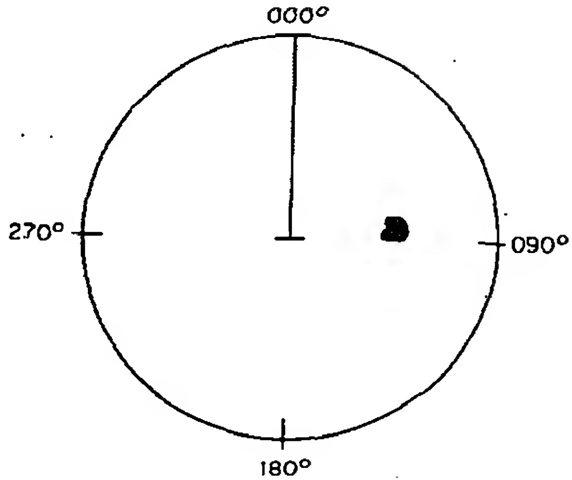
SWEEP WAVEFORM WITHOUT COMPENSATION

(B)

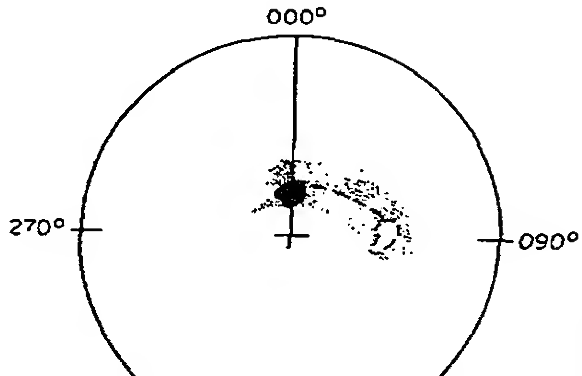
CORRECTLY COMPENSATED SWEEP WAVEFORM



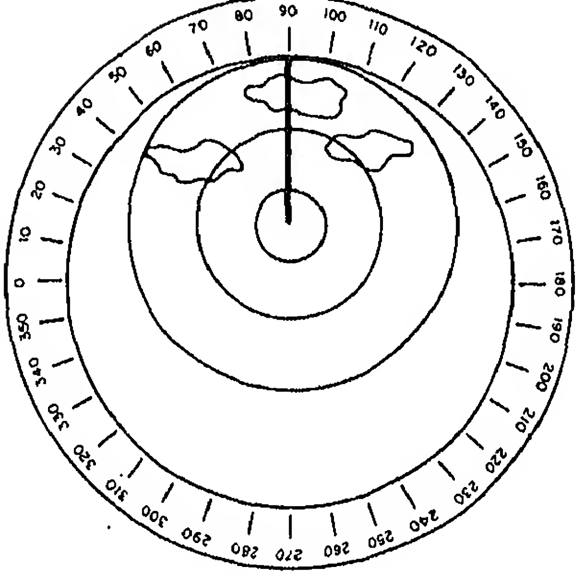
CLAMPER CIRCUIT

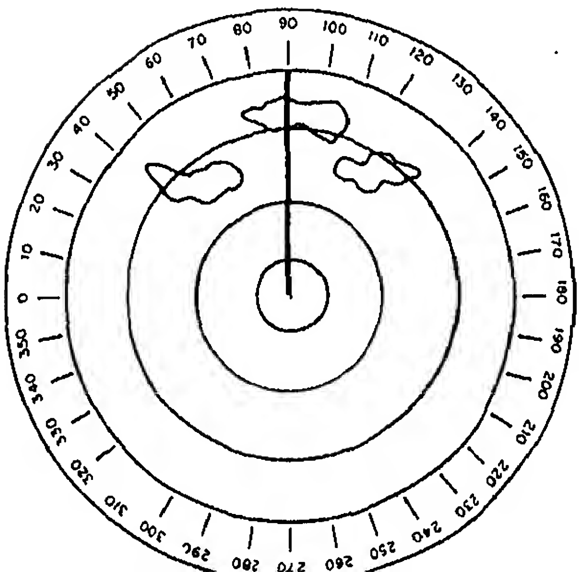


AIRCRAFT HEADING 000°.
TARGET OFF STARBOARD
WING.



AIRCRAFT HAS MADE 90°
TURN TO STARBOARD.
AIRCRAFT HEADING 090°,


0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350


0
10
20
30
40
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60
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80
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100
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120
130
140
150
160
170
180
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200
210
220
230
240
250
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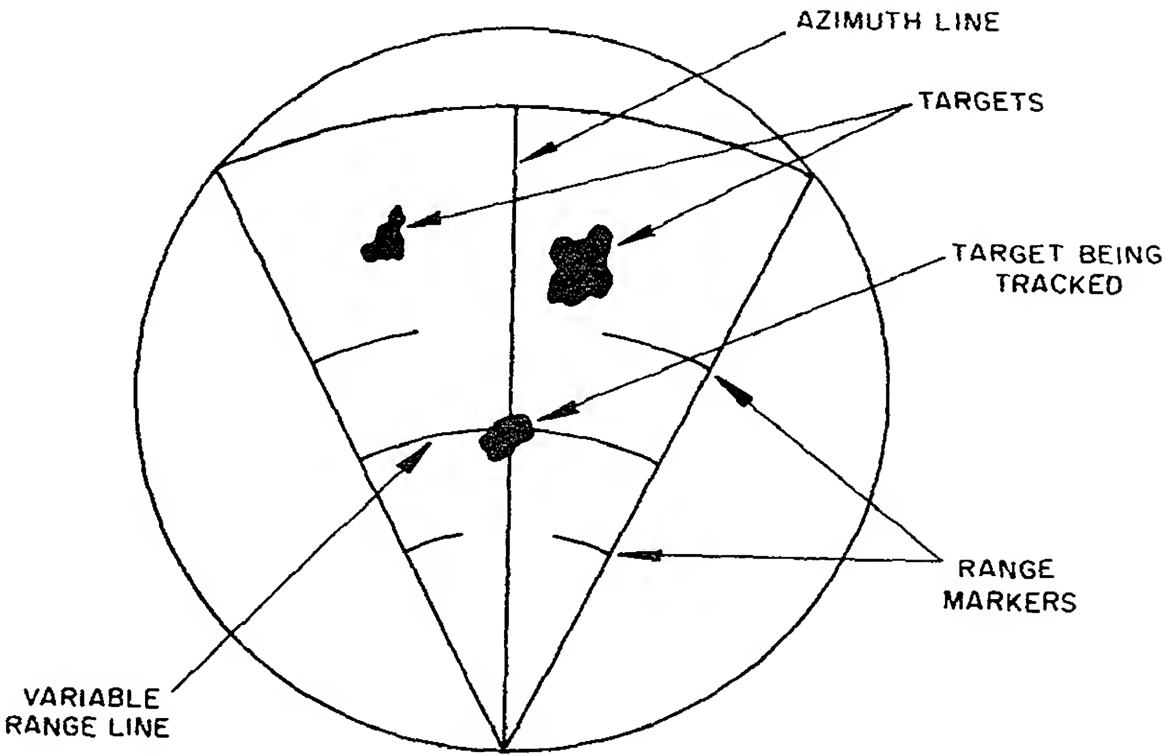
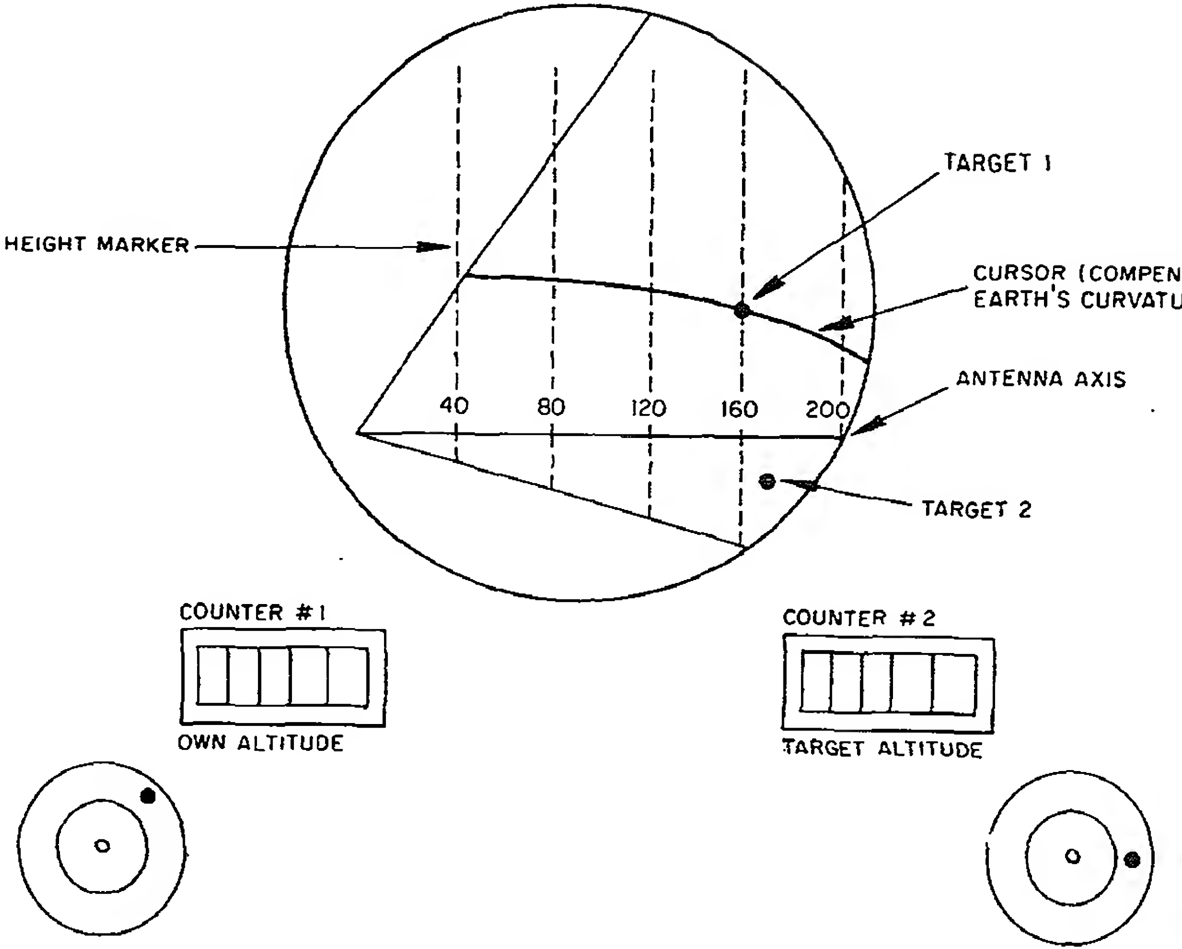
310
320
330
340
350



SECTOR SCAN PPI


TARGET 1
HEIGHT MARKER
CURSOR (COMPEN
EARTH'S CURVATU
ANTENNA AXIS
40
80
120
160
200
TARGET 2
COUNTER #1
OWN ALTITUDE
COUNTER # 2
TARGET ALTITUDE

11.7.1 Given statements concerning target parameters i
radar, select the correct statement(s).

11.7.2 Given statements concerning the advantages and
of a search mode on a tracking radar, compared
separate radars, select the correct statement(s

11.7.3 Given statements concerning the principles of c
sequential lobing tracking radar, select the co
ment(s).

11.7.4 Given a block diagram of a conical-scan trackin
statements concerning the error signal composit
the correct statement(s).

11.7.5 Given statements concerning the advantages of m
techniques over sequential lobing techniques, s
correct statement(s).

11.7.6 Given statements concerning range determinatio
derived from single plane sensing and the basic
monopulse radar, select the correct statement(s

11.7.7 Given a block diagram of a two coordinate ampl
monopulse tracking radar and statements concern
channel is used for elevation and azimuth angl
tion select the correct statement(s).

11.7.8 Given statements concerning the operational ch
of a track-while-scan (TWS) radar, select the
ment(s).

STUDY ASSIGNMENT

Read: 1. Aviation Fire Control Technician 3 & 2
NAVTRA 10387B pages 176-182.
2. Information Sheet 11.7.1I "Radar Track

Complete: Student Activity Guide 11.7.1S

STUDY QUESTIONS: None

is the minimum number of lobes required to provide two
dinate angular error information in a sequential lobing
king radar?

type of signal waveform does the concial scan error signal
mble?

is the difference between monopulse and sequential lobing
niques?

h channel of a single plane sensing monopulse provides range
rmation?

Sum
Difference
Both A and B
Neither A or B

many receive channels are there in a dual plane sensing
pulse?

1
2
3
4

k while scan radar requires ______ consecutive contacts to
ire a track and ______ consecutive blank scans to terminate

1. Introduction to Radar Systems, Skolnik, McGraw
Chapter 5

2. NAVEDTRA 10387B pages 176-182

INFORMATION:

I. TRACKING RADAR

A. Tracking With Radar

A tracking-radar system measures the coordinat
and provides data which may be used to determi
path and to predict its future position. All
of the available radar data -- range, elevatio
azimuth angle, and doppler frequency shift--ma
predicting future position; that is, a radar m
range, in angle, in doppler, or with any combi
Almost any radar can be considered a tracking
its output information is processed properly.
general, it is the method by which angle track
plished that distinguishes what is normally co
tracking radar from any other radar. It is al
to distinguish between a continuous tracking r
track-while-scan (TWS) radar. The former supp
tracking data on a particular target, while th
scan supplies sampled data on one or more targ
general, the continuous tracking radar and the
employ different types of equipment.

The antenna beam in the continuous tracking ra
tioned in angle by a servomechanism actuated b
signal. The various methods for generating th
may be classified as sequential lobing, conica
simultaneous lobing or monopulse. The range a
frequency shift can also be continuously track
by servo-control loop actuated by an error sig
in the radar receiver. The information availa
tracking radar may be presented on a cathode-r
display for action by an operator, or may be s
automatic computer which determines the target
calculates its probable future course.

employ a separate search radar to provide the information necessary to position the tracker on the target. A search radar, when used for this purpose, its called an acquistion radar. The acquisition radar designates targets to the tracking radar by providing the coordinates where the targets are to be found. The tracking radar acquires a target by performing a limited search in the area of the designated target coordinates.

The scanning fan-beam search radar can also provide tracking information to determine the path of the target and predict its future position. Each time the radar beam scans past the target, its coordinates are obtained. If the change in target coordinates from scan to scan is not too large, it is possible to reconstruct the track of the target from the sampled data. This may be accomplished by providing the PPI-scope operator with a grease pencil to mark the target pips on the face of the scope. A line joining those pips that correspond to the same target provides the target track. When the traffic is so dense that operators cannot maintain pace with the information available from the radar the target trajectory data may be processed automatically in a digital computer. The availability of small, inexpensive minicomputers has made it practical to obtain target tracks, not just target detections, from a surveillance radar. Such processing is usually called ADT (automatic detection and track). When the outputs from more than one radar are automatically combined to provide target tracks, the processing is called ADIT (automatic detection and integrated track) or IADT (integrated ADT).

A surveillance radar that provides target tracks is sometimes called a track-while-scan radar. This terminology is also applied to radars that scan a limited angular sector to provide tracking information at a high data rate on one or more targets within its field of view. Landing radars used for GCA (ground control of approach) and some missile control radars are of this type.

When the term tracking radar is used in this information sheet it generally refers to the continuous tracker, unless otherwise specified.

error zero. When the angular error is zero, the tar located along the reference direction.

One method of obtaining the direction and the magnit the angular error in one coordinate is by alternatel switching the antenna beam between two positions. T called lobe switching, sequential switching, or sequ lobing. *Figure 1 is a polar representation of the a* beam (minus the sidelobes) in the two switched posit plot in rectangular coordinates is shown in Figure 1 the error signal obtained from a target not on the s axis (reference direction) is shown in Figure 1c. T *difference in amplitude* between the voltages obtaine two switched positions is a measure of the angular d ment of the target from the switching axis. The sig difference determines the direction the antenna must moved in order to align the switching axis with the tion of the target. When the voltages in the two sw positions are equal, the target is on axis and its p may be determined from the axis direction.

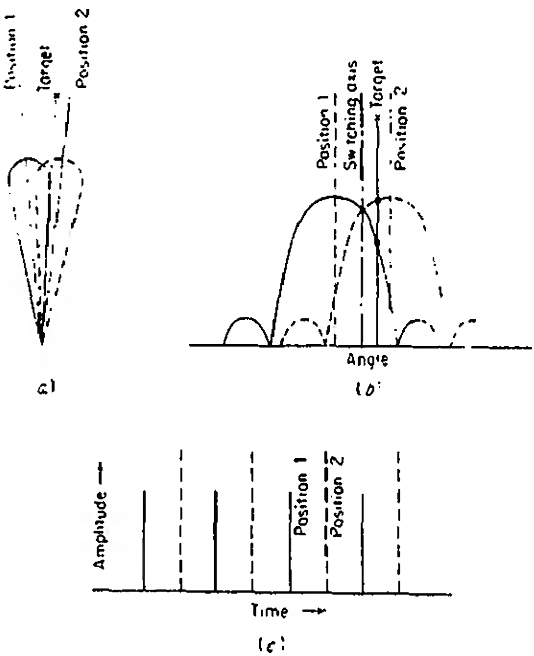


Figure 1

stepped in this five-feed arrangement.

One of the limitations of a simple unswitched nonscanning pencil-beam antenna is that the angle accuracy can be no better than the size of the antenna beamwidth. An important feature of sequential lobing (as well as the other tracking techniques to be discussed) is that the target-position accuracy can be far better than that given by the antenna beamwidth. The accuracy depends on how well equality of the signals in the switched positions can be determined. The fundamental limitation to accuracy is system noise caused either by mechanical or electrical fluctuations.

Sequential lobing, or lobe switching, was one of the first tracking-radar techniques to be employed. Early applicatio were in airborne-interception radar, where it provided directional information for homing on a target, and in ground-based antiaircraft fire-control radars. It is not used as often in modern tracking-radar applications as some of the other techniques to be described.

CONICAL SCAN

A logical extension of the simultaneous lobing techniques described in the previous section is to rotate continuously an offset antenna beam rather than discontinuously step the beam between four discrete positions. This is known as *conical scanning* (Figure 2). The angle between the axis of rotation (which is usually, but not always, the axis of the antenna reflector) and the axis of the antenna beam is called the squint angle. Consider a target at position A. The echo signal will be modulated at a fréquency equal to the rotation frequency of the beam. The amplitude of the echo-signal modulation will depend upon the shape of the antenna pattern, the squint angle, and the angle between the target line of sight and the rotation axis. The phase of the modulation depends on the angle between the target and the rotation axis. The conical-scan modulation is extracted from the echo signal and applied to a servo-contr system which continually positions the antenna on the targe [Note that two servos are required because the tracking problem is two-dimensional. Both the rectangular (az-el) and polar tracking coordinates may be used.] When the antenna is on target, as in B of Figure 2, the line of sigh to the target and the rotation axis coincide, and the conical-scan modulation is zero.

rotates, it is called a nutating feed. A rotating fe
causes the polarization to rotate. The latter type o
requires a rotary joint. The nutating feed requires
flexible joint. If the antenna is small, it may be e
to rotate the dish, which is offset, rather than the
thus avoiding the problem of a rotary or flexible RF
in the feed. A typical conical-scan rotation speed m
30 r/s. The same motor that provides the conical-sca
rotation of the antenna beam also drives a two-phase
reference generator with two outputs 90° apart in pha
These two outputs serve as a reference to extract the
tion and azimuth errors. The received echo signal is
the receiver from the antenna via two rotary joints (
shown in the block diagram). One rotary joint permit
motion in azimuth; the other, in elevation.

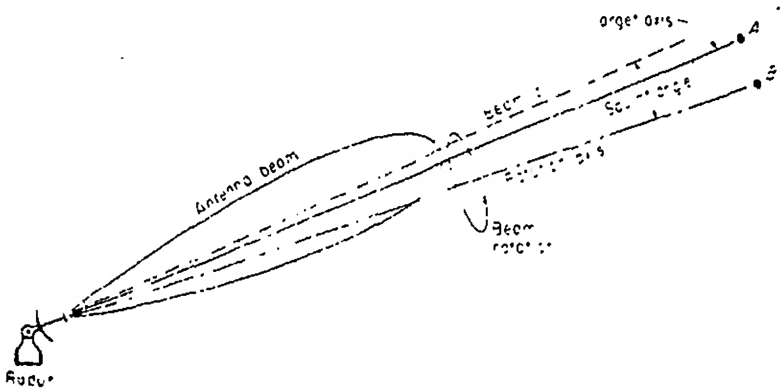
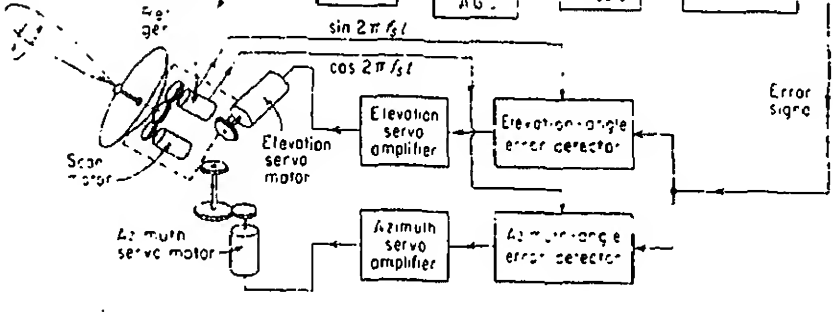


Figure 2 Conical-Scan Tracking.



'igure 3 Block diagram of conical-scan tracking radar.

The receiver is a conventional superheterodyne except for features peculiar to the conical-scan tracking radar. One feature not found in other radar receivers is a means of extracting the conical-scan modulation, or error signal. This is accomplished after the second detector in the video portion of the receiver. The error signal is compared with the elevation and azimuth reference signals in the angle-err detectors, which are phase-sensitive detectors. A phase-sensitive detector is a nonlinear device in which the input signal (in this case the angle-error signal) is mixed with the reference signal. The input and reference signals are of the same frequency. The output d-c voltage reverses polarity as the phase of the input signal changes through 180°. The magnitude of the d-c output from the angle-error detector is proportional to the error, and the sign (polarit is an indication of the direction of the error. The angle-error-detector outputs are amplified and drive the antenna elevation and azimuth servo motors.

The angular position of the target may be determined from the elevation and azimuth of the antenna axis. The positior can be read out be means of standard angle transducers such as synchros, potentiometers, or analog-to-digital-data converters.

generator eliminates the pulse repetition frequency a
reduces its harmonics. It also has the practical adv
that the magnitude of the conical-scan modulation is
fied because pulse stretching puts more of the availa
energy at the modulation frequency. The pulse repeti
frequency must be sufficiently large compared with th
conical-scan frequency for proper boxcar filtering.
it may be necessary to provide additional filtering t
attenuate undesired cross-modulation frequency compon

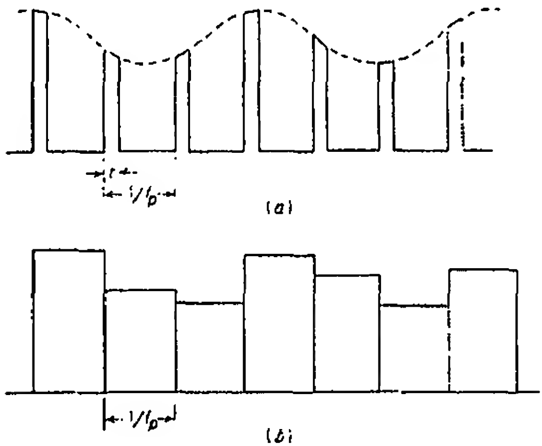


Figure 4

Other considerations. In both the sequential-lobing
conical-scan techniques, the measurement of the angle
in two orthogonal coordinates (azimuth and elevation)
that a minimum of three pulses be processed. In prac
however, the minimum number of pulses in sequential l
is usually four--one per quadrant. Although a conica
radar can also be operated with only four pulses per
tion, it is more usual to have ten or more per revolu
This allows the modulation due to the angle error to
that of a continuous sine wave. Thus the prf is usua
least an order of magnitude greater than the conical-
frequency. The scan frequency also must be at least
order of magnitude greater than the tracking bandwidt

scan, the train of echo pulses must contain no amplitude-modulation components other than the modulation produced by scanning. If the echo pulse-train did contain additional modulation components, caused, for example, by a fluctuating target cross section, the tracking accuracy might be degraded, especially if the frequency components of the fluctuations were at or near the conical-scan frequency or the sequential-lobing rate. The effect of the fluctuating echo can be sufficiently serious in some applications to severely limit the accuracy of those tracking radars which require many pulses to be processed in extracting the error signal.

Pulse-to-pulse amplitude fluctuations of the echo signal have no effect on tracking accuracy if the angular measurement is made on the basis of one pulse rather than many. There are several methods by which angle-error information might be obtained with only a single pulse. More than one antenna beam is used simultaneously in these methods, in contrast to the conical-scan or lobe-switching tracker, which utilizes one antenna beam on a time-shared basis. Th angle of arrival of the echo signal may be determined in a single-pulse system by measuring the relative phase or the relative amplitude of the echo pulse received in each beam. The names simultaneous lobing and monopulse are used to describe those tracking techniques which derive and angle-error information on the basis of a single pulse.

An example of a simultaneous-lobing technique is amplitude-comparison monopulse, or more simply, monopulse. In this technique the RF signals received from two offset antenna beams are combined so that both the sum and the difference signals are obtained simultaneously. The sum and differenc signals are multiplied in a phase-sensitive detector to obtain both the magnitude and the direction of the error signal. All the information necessary to determine the angular error is obtained on the basis of a single pulse; hence the name monopulse is quite appropriate.

Amplitude-comparison monopulse. The amplitude-comparison monopulse employs two overlapping antenna patterns (Figure 5a) to obtain the angular error in one coordinate. The twc overlapping antenna beams may be generated with a single reflector or with a lens antenna illuminated by two adjacer feeds. (A cluster of four feeds may be used if both elevat and azimuth-error signals are wanted.) The sum of the two

A block diagram of the amplitude-comparison-monopulse tracking radar for a single angular coordinate is shown in Figure 6. The two adjacent antenna feeds are connected to the two arms of a hybrid junction such as a "magic T," a "rat race," or a short-slot coupler. The sum and difference signals appear at the two other arms of the hybrid. On reception, the outputs of the sum arm and the difference arm are each heterodyned to an intermediate frequency and amplified as in any superheterodyne receiver. The transmitter is connected to the sum arm. Range information is also extract from the sum channel. A duplexer is included in the sum arm for the protection of the receiver. The output of the phase-sensitive detector is an error signal whose magnitude is proportional to the angular error and whose sign is proportional to the direction.

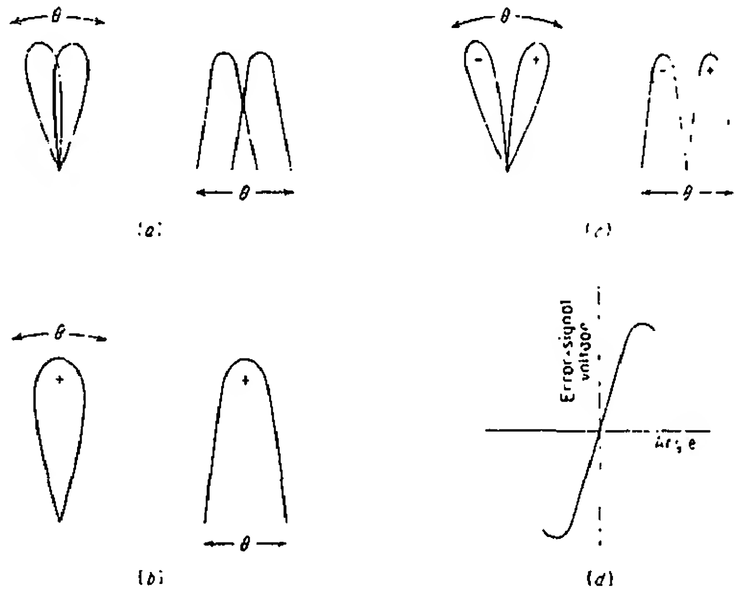
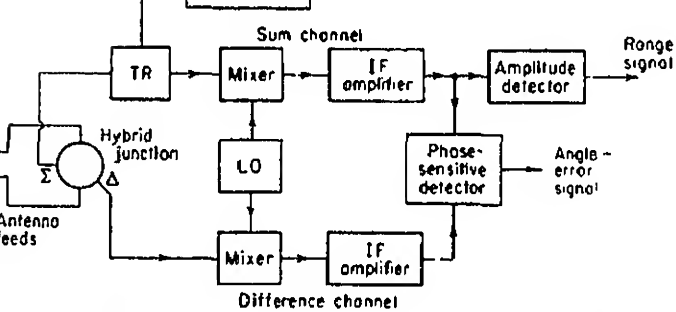


Figure 5

The output of the monopulse radar is used to perform automat tracking. The angular-error signal actuates a servo-control system to position the antenna, and the range output from the sum channel feeds into an automatic-range-tracking unit



Block diagram of amplitude-comparison monopulse radar (one angular coordinate).

Figure 6

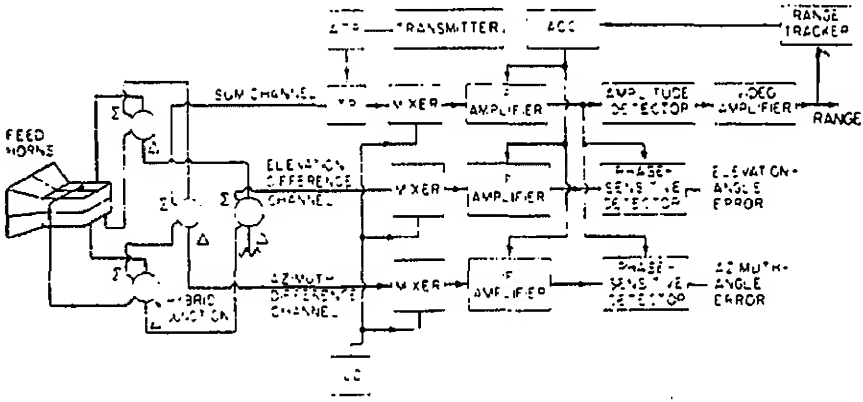
signal in the IF portion of the receiver were $A_s \cos \omega_{IF}t$, difference signal would be either $A_d \cos \omega_{IF}t$ or -- os $\omega_{IF}t(A_s > 0, A_d > 0)$, depending on which side of ter is the target. Since $-- A_d \cos\omega_{IF}t = A_d \cos \omega_{IF}(t + \pi)$, sign of the difference signal may be measured by deter- ing whether the difference signal is in phase with the sum 180° out of phase.

hough a phase comparison is a part of the amplitude- parison-monopulse radar, the angular-error signal is ically derived by comparing the echo amplitudes from ultaneous offset beams. The phase relationship between signals in the offset beams is not used. The purpose of phase-sensitive detector is to conveniently furnish the n of the error signal.

lock diagram of a monopulse radar with provision for racting error signals in both elevation and azimuth is wn in Figure 7. The cluster of four feeds generates four tially overlapping antenna beams. The feeds might be d with a parabolic reflector, Cassegrain antenna, or a s. All four feeds generate the sum pattern. The ference pattern in one plane is formed by taking the sum two adjacent feeds and subtractng this from the sum of other two adjacent feeds. The difference pattern in the

Since a phase comparison is made between the output of the sum channel and each of the difference channels, it is important that the phase shifts introduced by each of the channels be almost identical. According to Page, the phase difference between channels must be maintained to within 25 or better for reasonably proper performance. The gains of the channels also must not differ by more than specified amounts.

An alternative approach to using three identical amplifiers in the monopulse receiver is to use but one IF channel whic amplifies the sum signal and the two difference signals on time-shared basis. The sum signal is passed through the single IF amplifier followed by the two difference signals delayed in time by a suitable amount. Most of the gain and



ce 7 Block diagram of two-coordinate (azimuth and elevation) amplitude-comparison monopulse tracking radar.

gain control take place in the single IF amplifier. Any variations affect all three signals simultaneously. After amplification, compensating delays are introduced to unscramble the time sequence and bring the sum signal and the two difference signals in time coincidence. Phase detectio occurs as in the conventional monopulse. Another single-channel system SCAMP converts the sum and the two differenc signals to different IF frequencies and amplifies them simultaneously in a single, wide-band amplifier. The outpu is hard-limited to provide the effect of an instantaneous

is to ease the problem associated with maintaining identica phase and amplitude balance among the three channels of the conventional receiver. These techniques provide some advantage in this regard but they can result in undesired coupling between the azimuth and elevation channels and a loss in signal-to-noise ratio.

The monopulse antenna must generate a sum pattern with high efficiency (maximum boresight gain), and a difference patte with a large value of slope at the crossover of the offset beams. Furthermore, the sidelobes of both the sum and the difference patterns must be low. The antenna must be capal of the desired bandwidth, and the patterns must have the desired polarization characteristics. It is not surprisin that the achievement of all these properties cannot always be fully satisfied simultaneously. Antenna design is an important part of the successful realization of a good monopulse radar.

TRACKING IN RANGE

In most tracking-radar applications the target is continuously tracked in range as well as in angle. Range tracki might be accomplished by an operator who watches an A-scop or J-scope presentation and manually positions a handwheel in order to maintain a marker over the desired target pip. The setting of the handwheel is a measure of the target range and may be converted to a voltage that is supplied t a data processor.

As target speeds increase, it is increasingly difficult fo an operator to perform at the necessaary levels of efficie over a sustained period of time, and automatic tracking becomes a necessity. Indeed, there are many tracking applications where an operator has no place, as in a homin missile or in a small space vehicle.

The technique for automatically tracking in range is based on the split range gate. Two range gates are generated as shown in Figure 8. One is the early gate, and the other i the late gate. The echo pulse is shown in Figure 8a the relative position of the gates at a particular instant in Figure 8b and the error signal in Figure 8c. The portion the signal energy contained in the early gate is less than that in the late gate. If the outputs of the two gates ar subtracted, an error signal (Figure 8c) will result which

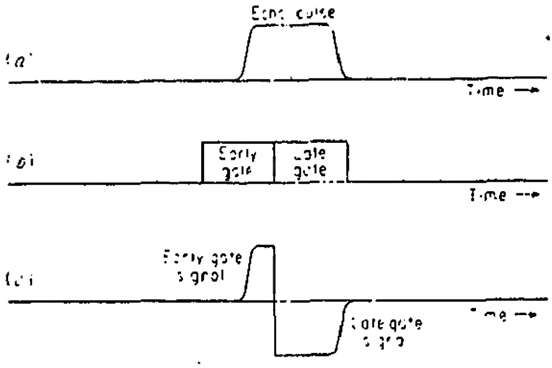


Figure 8

The range gating necessary to perform automatic track
offers several advantages as by-products. It isolate
target, excluding targets at other ranges. This perm
boxcar generator to be employed. Also, range gating
the signal-to-noise ratio since it eliminates the no
the other range intervals. Hence the width of the ga
should be sufficiently narrow to minimize extraneous
On the other hand, it must not be so narrow that an a
ciable fraction of the signal energy is excluded. A
reasonable compromise is to make the gate width of th
of the pulse width.

A target of finite length can cause noise in range-t
circuits in an analogous manner to angle-fluctuation
(glint) in the angle-tracking circuits. Range-track
noise depends on the length of the target and its sh
has been reported that the rms value of the range no
approximately 0.8 of the target length when tracking
accomplished with a video split-range-gate error det

F. ACQUISITION

A tracking radar must first find and acquire its tar
before it can operate as a tracker. Therefore it is
necessary for the radar to scan an angular sector in
the presence of the target is suspected. Most track
radars employ a narrow pencil-beam antenna. Searchi
volume in space for an aircraft target with a narrow

radar, developed during World War II for the aiming of antiaircraft-gun batteries. The SCR-584 antenna was rotated at the rate of 6rpm and covered a 20° elevation angle in 1 min. The Palmer scan derives its name from the familiar penmanship exercises of grammar school days. It consists of a rapid circular scan (conical scan) about the axis of the antenna, combined with a linear movement of the axis of rotation. When the axis of rotation is held stationary, the Palmer scan reduces to the conical scan. Because of this

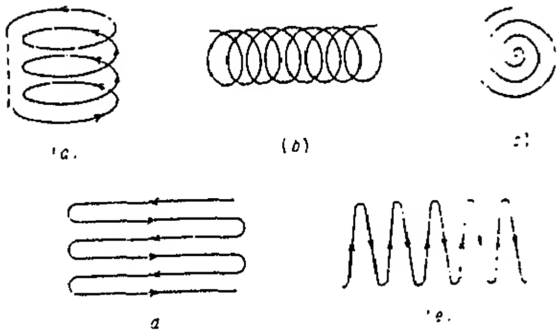


Figure 9

property, the Palmer scan is sometimes used with conical-scan tracking radars which must operate with a search as well as a track mode since the same mechanisms used to produce conical scanning can also be used for Palmer scanning. Some conical-scan tracking radars increase the squint angle during search in order to reduce the time required to scan a given volume. The conical scan of the SCR-584 was operated during the search mode and was actually a Palmer scan in a helix. In general, conical scan is performed during the search mode of most tracking radars.

The Palmer scan is suited to a search area which is larger in one deminesion than another. The spiral scan covers an angular search volume with circular symmetry. Both the spiral scan and the Palmer scan suffer from the disadvantage that all parts of the scan volume do not receive the same

raster scan--nodding scan many also be used to o
spherical coverage, that is, elevation angle ext
90° and the azimuth scan angle to 360°.

The helical scan and the nodding scan can both b
obtain hemispheric coverage with a pencil beam.
scan is also used with height-finding radars.
spiral, and raster scans are employed in fire-co
tracking radars to assist in the aquisition of
when the search sector is of limited extent.

Tracking in doppler. Tracking radars that are b
pulse-doppler, or MTI principles can also track
frequency shift generated by a moving target.
accomplished with a frequency discriminator and
oscillator to maintain the received signal in th
a narrow-band filter. It is also possible to u
lock loop, or phase-sensitive discriminator who
drives a voltage-controlled oscillator to hold
step with the input signal. Tracking the doppl
shift with the equivalent of a narrow-band filt
enough to encompass the frequency spectrum of t
signal allows an improvement in the signal-to-n
compared with wideband processing. It can also
resolution of the desired moving target from st
clutter. The doppler tracking filter is someti
speed gate.

G. COMPARISON OF TRACKERS

Of the four continuous-tracking-radar technique
been discussed (sequential lobing, conical scan
comparison monopulse, and phase-comparison mono
conical scan and amplitude-comparison monopulse
more application than the other two. The phase
monopulse has not been too popular because of t
awkwardness of its antenna (four separate anten
to point their individual beams in the same dir
because the sidelobe levels might be higher tha
Although sequential lobing is similar to conica
latter is preferred in most applications, since
less loss and the antenna and feed systems are
complex. In this section, only the conical-sca
the amplitude-comparison monopulse will be comp
latter will be referred to simply as monopulse.

The tracking accuracy of a monopulse radar is superior to that of the conical-scan radar because of the absence of target amplitude-fluctuations and because of its greater signal-to-noise ratio. It is the preferred technique for precision tracking. However, both monopulse and conical-sca radars are degraded equally by the wandering of the apparen position of the target (glint).

The monopulse radar is the more complex of the two. Three separate receivers are necessary to derive the error signal in two orthogonal angular coordinates. Only one receiver i needed in the conical-scan radar. (There are certain monopulse implementations that can use either one or two receivers, but at some sacrifice in performance.) Since th monopulse radar compares the amplitudes of signals received in three separate channels, it is important that the gain and phase shift through these channels be identical. The R circuitry that generates the sum and difference signals in monopulse radar has been steadily improved, and can be realized without excessive physical bulk. A popular form o antenna for monopulse is the Cassegrain.

With the monopulse tracker it is possible to obtain a measu of the angular error in two coordinates on the basis of a single pulse. A minimum of four pulses are usually necessa with the conical-scan radar. However, a continuous-trackin radar seldom makes a measurement on a single pulse. (Phase array radars and some surveillance radars, however, might use the monopulse principle to extract an angle measurement on the basis of a single pulse.) In practice, the two radars utilize essentially the same number of pulses to obtain an error signal if the servo tracking bandwidths and pulse repetition frequencies are the same. The monopulse radar first makes its angle measurement and then integrates a number of pulses to obtain the required signal-to-noise ratio and to smooth the error. The conical-scan radar, on the other hand, integrates a number of pulses first and the extracts the angle measurement.

Because a monopulse radar is not degraded by amplitude fluctuations, it is less susceptible to hostile electronic countermeasures than is conical scan.

In brief, the monopulse radar is the better tracking technique; but in many applications where the ultimate in performance is not needed, the conical-scan radar is used because it is less costly and less complex.

One method of obtaining tracks with a sureveillance r
to have an operator manually mark with grease pencil
face of the cathode-ray tube the location of the targ
each scan. The simplicity of such a procedure is off
the poor accuracy of the track. The accuracy of trac
be improved by using a computer to determine the traj
from inputs supplied by an operator. A human operato
however, cannot update target tracks at a rate greate
about once per two seconds. Thus, a single operator
handle more than about six target tracks when the rad
a twelve-second scan rate (5 rpm antenna rotation rat
Furthermore an operator's effectiveness in detecting
targets decreases rapidly after about a half hour of
tion. The radar operator's traffic handling limitati
the effects of fatigue can be mitigated by automating
target detection and tracking process with data proce
called automatic detection and tracking (ADT). The a
ability of digital data processing technology has mad
economically feasible. An ADT system performs the fu
of target detection, track initiation, track associat
track update, track smoothing (filtering) and track t
tion.

The automatic detector part of the ADT quantizes the
into intervals equal to the range resolution. At eac
interval the detector integrates "n" pulses, where "n
the number of pulses expected to be returned from a t
as the antenna scans past. the integrated pulses are
with a threshold to indicate the presence or absence
target. An example is the commonly used moving windo
detector which examines continuously the last "n" sam
within each quantized range interval and announces th
presence of a target if "m" out of "n" of these sampl
cross a preset threshold. By locating the center of
pulses, an estimate of the target's angular directio
obtained. This is called beam splitting.

If there is but one target present within the radar'
coverage, then detections on two scans are all that
needed to establish a target track and to estimate it
velocity. However, there are usually other targets
as clutter echoes present, so that three or more dete
are needed to reliably establish a track without the
tion of false or spurious tracks. Although a compute
be programmed to recognize and reject false tracks,
false tracks can overload the computer and result in

characteristic, such as its altitude, might also prove of help when performing track association. Thus, the quality of the ADT will depend significantly on the ability of the radar to reject unwanted signals.

When a new detection is received, an attempt is made to associate it with existing tracks. This is aided by establishing for each track a small search region, or gate, within which a new detection is predicted based on the estimate of the target speed and direction. It is desired to make the gate as small as possible so as to avoid having more than one echo fall within it when the traffic density is high or when two tracks are close to one another. However, a large gate area is required if the tracker is to follow target turns or maneuvers. More than one size gate might therefore be used to overcome this dilemma. The size of the small gate would be determined by the accuracy of the track. When a target does not appear in the small gate, a larger gate would be used whose search area is determined by the maximum acceleration expected of the target during turns.

On the basis of the past detections the track-while-scan radar must make a smoothed estimate of a target's present position and velocity, as well as a predicted position and velocity. One method for computing this information is the so-called α-β tracker (also called the g-h tracker), which computes the present smoothed target position $\bar{x}_n$ and velocity $\bar{\dot{x}}$ by the following equations

$$\text{Smoothed position: } \bar{x}_n = x_{pn} + \alpha(x_n - x_{pn})$$

$$\text{Smoothed velocity: } \bar{\dot{x}}_n = \bar{\dot{x}}_{n-1} + \frac{\beta}{T_s}(x_n - x_{pn})$$

where x_{pn} = predicted position of the target at the nth scan, x_n = measured position at the nth scan, α = position smoothing parameter, β = velocity smoothing parameter, and T_s = time between observations. The predicted position at the n + 1st scan is $\bar{x}_n + \bar{\dot{x}}_n T_s$. (When acceleration is important a third equation can be added to describe an α-β-γ tracker, where γ = acceleration smoothing parameter.) For $\alpha = \beta = 0$, the tracker uses no current information, on

rapid response to maneuvering targets (requiring ... width). Another criterion for selecting the α-β c... ficients is based on the best linear track fitted to ... radar data in a least squares sense. This gives the ... of α and β as

$$\alpha = \frac{2(2n - 1)}{n(n + 1)} \quad \beta = \frac{6}{n(n + 1)}$$

where n is the number of the scan or target observat... (n > 2).

The standard α-β tracker does not handle the maneuve... target. However, an adaptive α-β tracker is one whi... varies the two smoothing parameters to achieve a var... bandwidth so as to follow maneuvers. The value of α ... set by observing the measurement error $x_n - x_{pn}$. At ... start of tracking the bandwidth is made wide and the ... narrows down if the target moves in a straight-line ... tory. As the target maneuvers or turns, the bandwid... widened to keep the tracking error small.

The Kalman filter is similar to the classical α-β tr... except that it inherently provides for the dynamical... maneuvering target. In the Kalman filter a model fo... measurement error has to be assumed, as well as a mo... the target trajectory and the disturbance or uncerta... the trajectory. Such disturbances in the trajectory ... be due to neglect of higher-order derivatives in the ... of the dynamics, random motions due to atmospheric ... and deliberate target maneuvers. The Kalman filter ... principle, utilize a wide variety of models for mea... noise and trajectory disturbance; however, it is oft... assumed that these are described by white noise with ... mean. A maneuvering target does not always fit such ... ideal model, since it is quite likely to produce co... observations. The proper inclusion of realistic dy... models increases the complexity of the calculations ... it is difficult to describe a priori the precise na... the trajectory disturbances. Some form of adaptati... maneuvers is required. The Kalman filter is sophis... and accurate, but is more costly to implement than ... several other methods commonly used for the smoothi... prediction of tracking data. Its chief advantage o...

and β accordingly. In some radar systems, the data rate might also be increased during target maneuvers. As the means for choosing α and β become more sophisticated, the optimal α-β tracker becomes equivalent to a Kalman filter even for a target trajectory model with error. In this sense, the optimal α-β tracking filter is one in which the values of α and β require knowledge of the statistics of th measurement errors and the prediction errors, and in which and β are determined in a recursive manner in that they depend on previous estimates of the mean square error in th smoothed position and velocity.

The above discussion has been in terms of a sampled-data system tracking targets detected by a surveillance radar. The concept of the α-β tracker or the Kalman filter also ca be applied to a continuous, single-target tracking radar when the error signal is processed digitally rather than analog. Indeed, the equations describing the α-β tracker are equivalent to the type II servo system widely used to model the continuous tracker.)

If for some reason, the track-while-scan radar does not receive target information on a particular scan, the smoothing and prediction operation can be continued by properly accounting for the missed data. However, when dat to update a track is missing for a sufficient number of consecutive scans the track is terminated. Although the criterion for terminating a track depends on the applicatio one example suggests that when three target reports are use to establish a track, five consecutive misses is a suitable criterion for termination.

One of the corollary advantages of ADT is that it effects a bandwidth reduction in the output of a radar so as to allow the radar data to be transmitted to another location via narrowband phone lines rather than wideband microwave links This makes it more convenient to operate the radar at a remote site, and permits the outputs from many radars to be communicated economically to a central control point.

It should be noted that the adaptive thresholding of the automatic detector can cause a worsening of the range-reso- lution. By analogy to the angular resolution possible in the angle coordinate it would seem a priori that two target might be resolved in range if the separation is about 0.8 o

3. What controls the phase and time relationships of the frequencies as they exit the LIFMOP filter?

4. What is the meaning of a "time domain?"

5. What is the meaning of a "frequency domain?"

What would be the bandwidth generated by applying a .5 usec pulse to a COMO?

a. 20MHz
b. 2MHz
c. 40MHz
d. 4MHz

A typical bandpass for the tuned amplifiers in each channel of the matched filter is:

a. 1 MHz
b. .5 MHz
c. 10 MHz
d. 5 MHz

List three advantages of pulse compression radar over conventional radars?

What contributes to the high resolution capabilities of the chirp radar?

11.9.1 Given statements concerning the difference bet radar echoes from fixed and moving targets, se the correct statement(s).

11.9.2 Given a block diagram of a delay line canceler list of statements, match the correct statemen with the appropriate block.

11.9.3 Given statements concerning the operating prin of a noncoherent MTI radar, select the correct statements.

11.9.4 Given statements concerning the operating prin of a coherent MTI radar, select the correct st ments.

11.9.5 Given statements concerning blind speeds in MT radar, select the correct statements.

11.9.6 Given statements concerning relative advantage disadvantages of coherent and noncoherent MTI select the correct statements.

STUDY ASSIGNMENT:

Read: 1. Aviation Electronics Technician 1 and NAVTRA 10318-D, Chapter 8, pp 226-228.
2. Information Sheet No. 11.9.1I "MOVING TA INDICATOR RADAR".

Complete: Student Activity Guide 11.9.1S

STUDY QUESTIONS: None

b. Display moving targets as a line of video on the display.

c. Display moving targets only.

d. Display moving and stationary targets.

2. What is the purpose of the Coho?

a. Internal reference

b. External reference

c. Pulsing oscillator

d. To discriminate between stationary and moving targets.

3. What is the external reference for the noncoherent radar?

a. Coho

b. Como

c. Moving targets

d. Stationary targets

4. What is the purpose of the delay line canceler?

a. To cancel the effects of the delay line.

b. To cancel moving targets

c. To cancel stationary targets

d. To repeat several times and keep the image on t screen.

c. Phases of each channel must be matched

d. Phases of each channel must be mismatched.

6. Which of the following could be used to delay t
in the delay channel of the delay line canceler

a. Magnetostrictive

b. Quartz

c. Mercury

d. PFN

7. At what velocities do blind speeds occur?

a. 100 Kts

b.. 500 Kts

c. PRF of the radar

d. When the velocity of the target produces a
shift equal to or a multiple of the PRF of
radar.

radar systems. They must have the capabilities of locating the enemy in all kinds of weather, day or night. Because of the speeds that newer aircraft are traveling, both friend and foe, the radar system must give accurate range resolution, and in some cases, whether or not the target is moving and the direction it is moving. No longer can the radar operator be solely depended upon to distinguish moving objects.

Today, there are radar systems of this nature already in operation in the fleet, both in attack aircraft (A6A Intruder) and long range, early warning aircraft (E2A, Hawkeye). Radar systems that have these capabilities are known as moving target indicator (MTI) and airborne moving target indicator (AMTI).

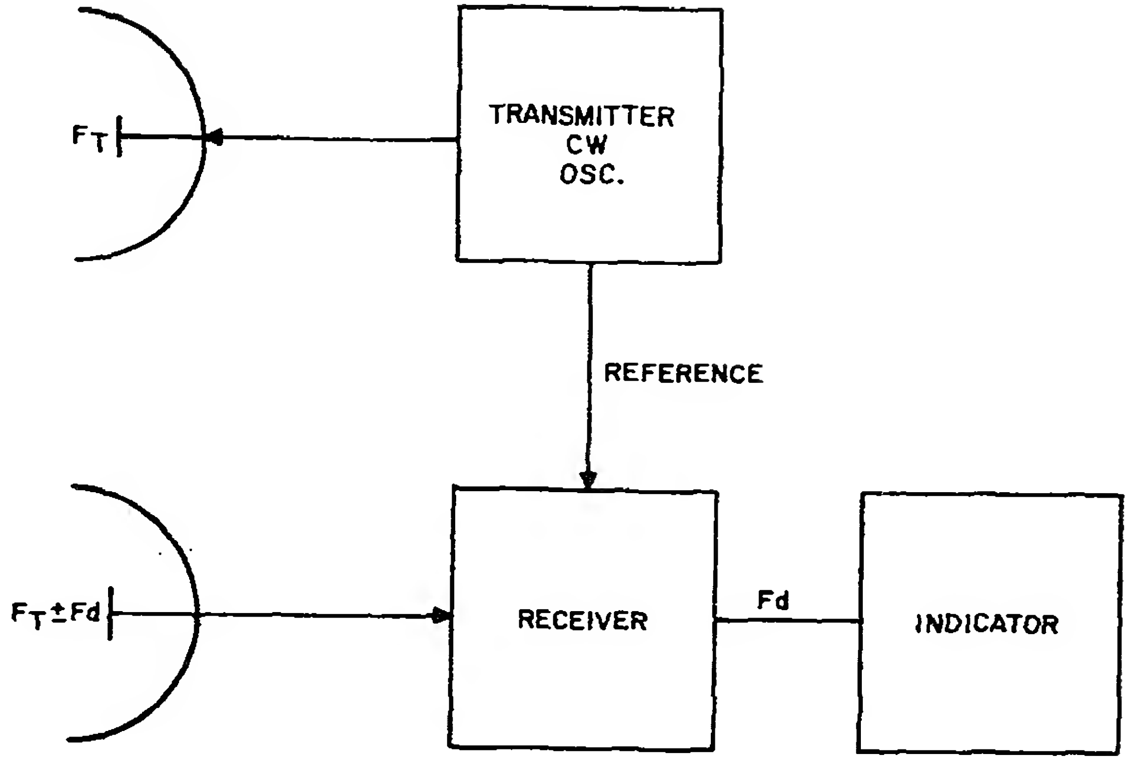
FERENCES: Introduction to Radar Systems, SKOLNIK, Mcgraw Hill, 1980, Chapter 4.

FORMATION

HERENT SYSTEMS

The Doppler shift in frequency caused by a moving target may be used in pulse radar to distinguish fixed from moving targets. The fixed targets are called clutter because they tend to clutter the CRT of conventional radars. The AMTI can extract the moving target echo from the clutter echo even if the clutter echo is 20 to 30 db greater than the moving echo.

Figure 1 is a simple c-w radar block diagram. The c-w oscillator serves as the transmitter and as the referen signal source. A moving target would cause the transmitted frequency (f_t) to have an up or down d_s; therefo the received frequency would be $E_T \pm F_d$. The receiver compares the return frequency with the reference freque The F_{ds} would then be detected and sent to the indicato No F_d would be detected from a fixed target; thus, only moving targets would be seen on the CRT. This simple system has the disadvantage of not providing range information.



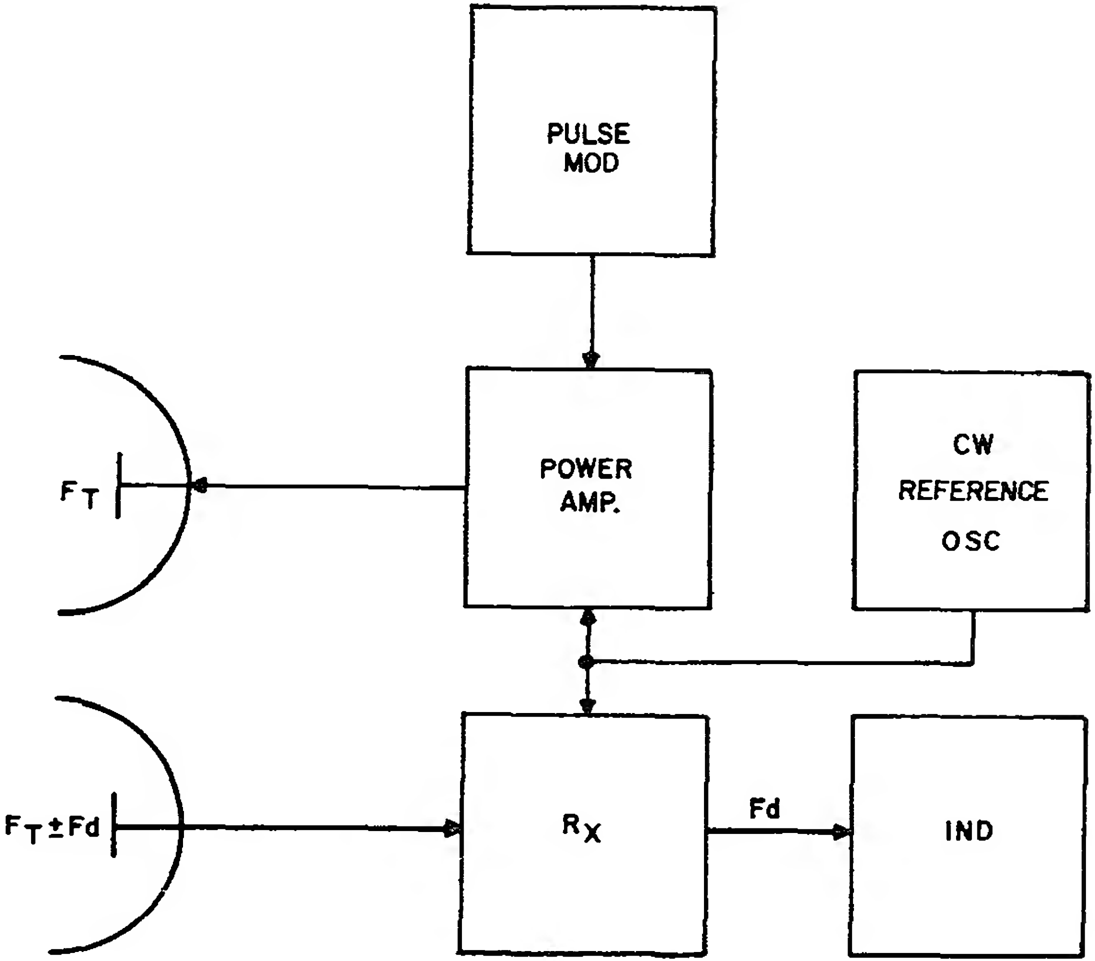
BLOCK DIAGRAM OF A BASIC DOPPLER MTI

In the coherent MTI, there has to be a definite phase relationship between the transmitted signal and the reference oscillator. The reference oscillator will be a coherent c-w oscillator, normally abbreviated COHO. Since the COHO and transmitter frequency must have a definite phase relationship, the phase of the COHO is locked to the phase of the transmitted pulse each time the transmitter fires.

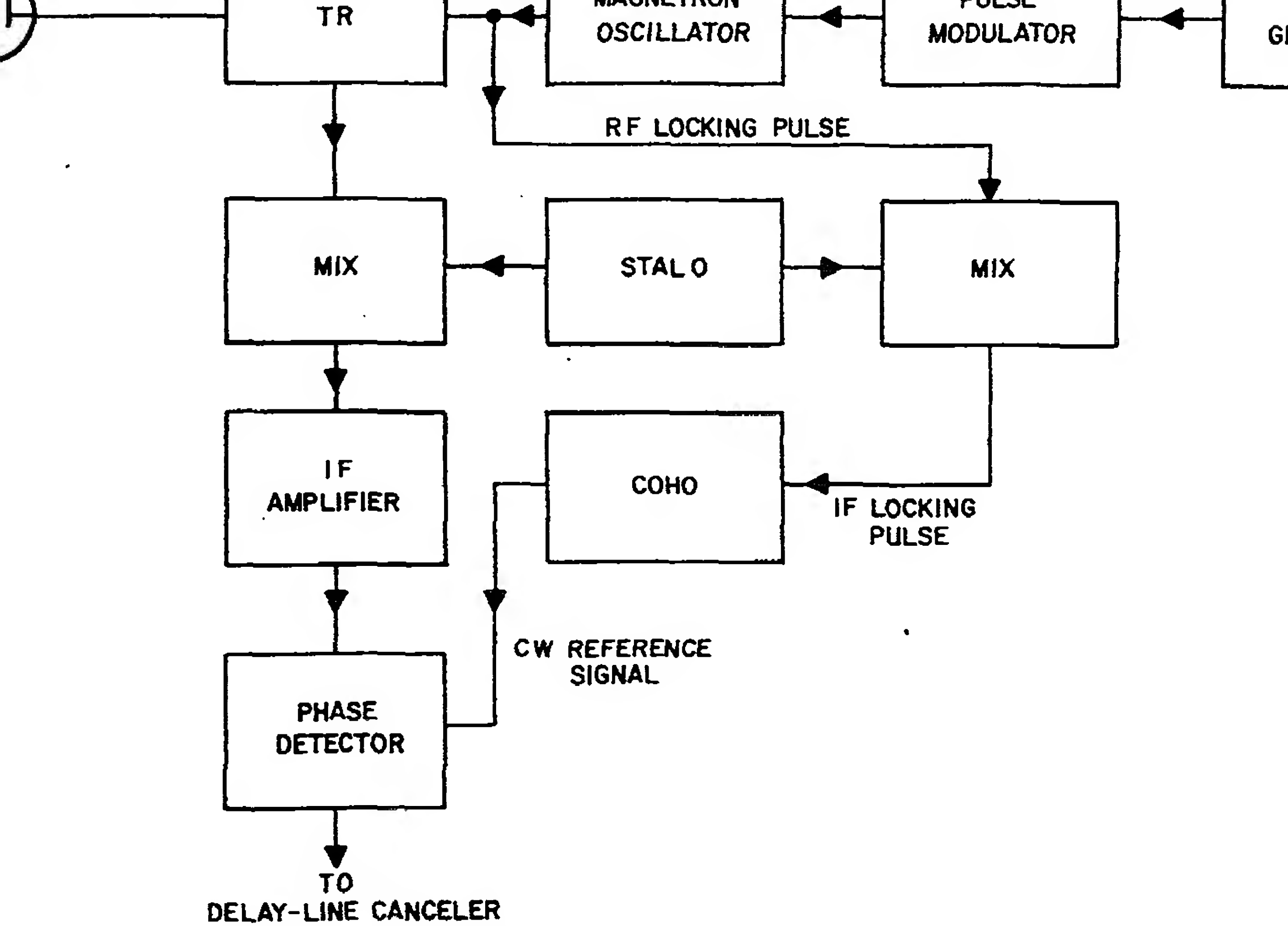
Figure 3 shows a block diagram of a coherent AMTI system. The transmitted r-f pulse is fed to the antenna for transmission and also is fed to a mixer where it is mixed with the local oscillator. The local oscillator must be very stable so a stable local oscillator (STALO) is used to provide the frequency translation needed. The output of the mixer is the i-f locking pulse that is used to lock the phase of the COHO to the transmitter. As can be seen, the COHO operates at the i-f frequency. The output from the COHO is then fed to the phase shifter. The other input to the phase shifter is from a servo which receives inputs fo A/C velocity and antenna azimuth. The phase shifter provides the reference for detection of the moving target's return.

The received signal goes through the mixer, i-f amplifier, and then to the phase detector. The phase detector detects any phase difference between the received frequency and the COHO. The voltage from the phase detector is fed to the delay line canceler (delay line cancelers will be covered later in this information sheet).

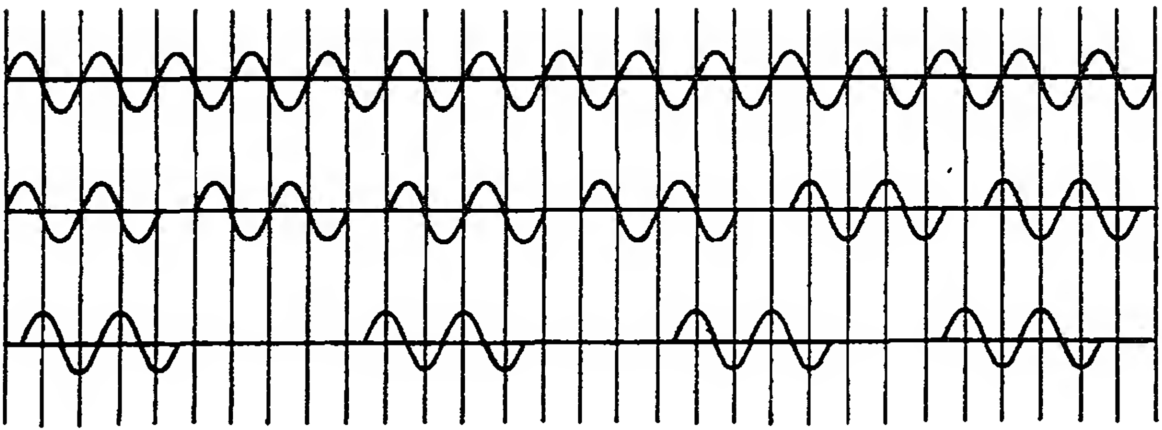
To understand what causes the phase difference between the received signal and the COHO we must look at what happens during the time of transmit and reception of the signal. (Refer to figure 4.) The transmitted pulse will return to the receiver with the same phase as it was when transmitted. The COHO is operated c-w so its phase may or may not be the same as the received signal. The transmitted pulse returns at T_O + Range; if it was negative going at T_O it will return with that same phase and be compared to the phase of the COHO at that time. If the target is stationary or if the target moves a



BLOCK DIAGRAM OF A PULSED-DOPPLER MTI



BLOCK DIAGRAM OF MTI RADAR WITH POWER OSCILLATOR TRANSMITTER


COHO
RETURNS FR
MOVING TAR
RETURNS FR
STATIONARY
BLIND SPEE

compared to a different phase of the COHO. This varying phase causes a varying voltage out of the phase detector and would not be canceled in the delay line canceler.

NONCOHERENT MTI

A. The composite echo signal from a moving target and clutter fluctuates in both phase and amplitude. (Refer to figure 5.) The coherent MTI and the Doppler radar make use of the phase fluctuations.

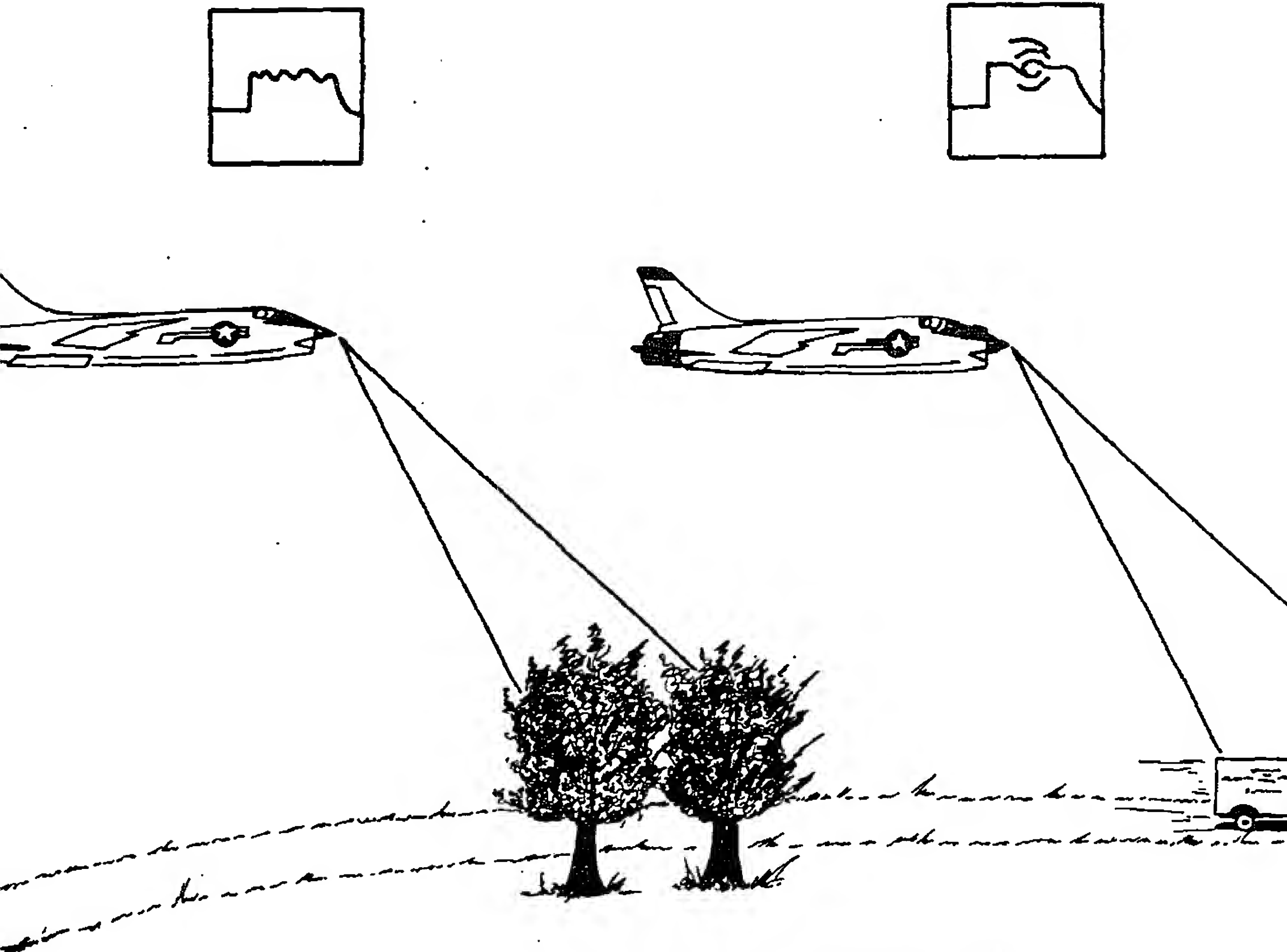
B. It is also possible to use the amplitude fluctuations recognize the Doppler component produced by a moving target. MTI radar that uses this principle is called noncoherent or externally coherent MTI. (Refer to figure 6.) The noncoherent MTI radar does not need an internal coherent oscillator. Amplitude limiting cann be employed in the noncoherent MTI radar, because the desired amplitude fluctuations would be lost. Therefo the i-f amplifier must be linear, or if a large dynami range is required, it can be logarithmic.

C. The detector following the i-f amplifier is a conventional amplitude detector. The local oscillator of th noncoherent radar does not have to be as frequency-sta as the coherent MTI. The output of the amplitude dete is fed to a delay line canceler.

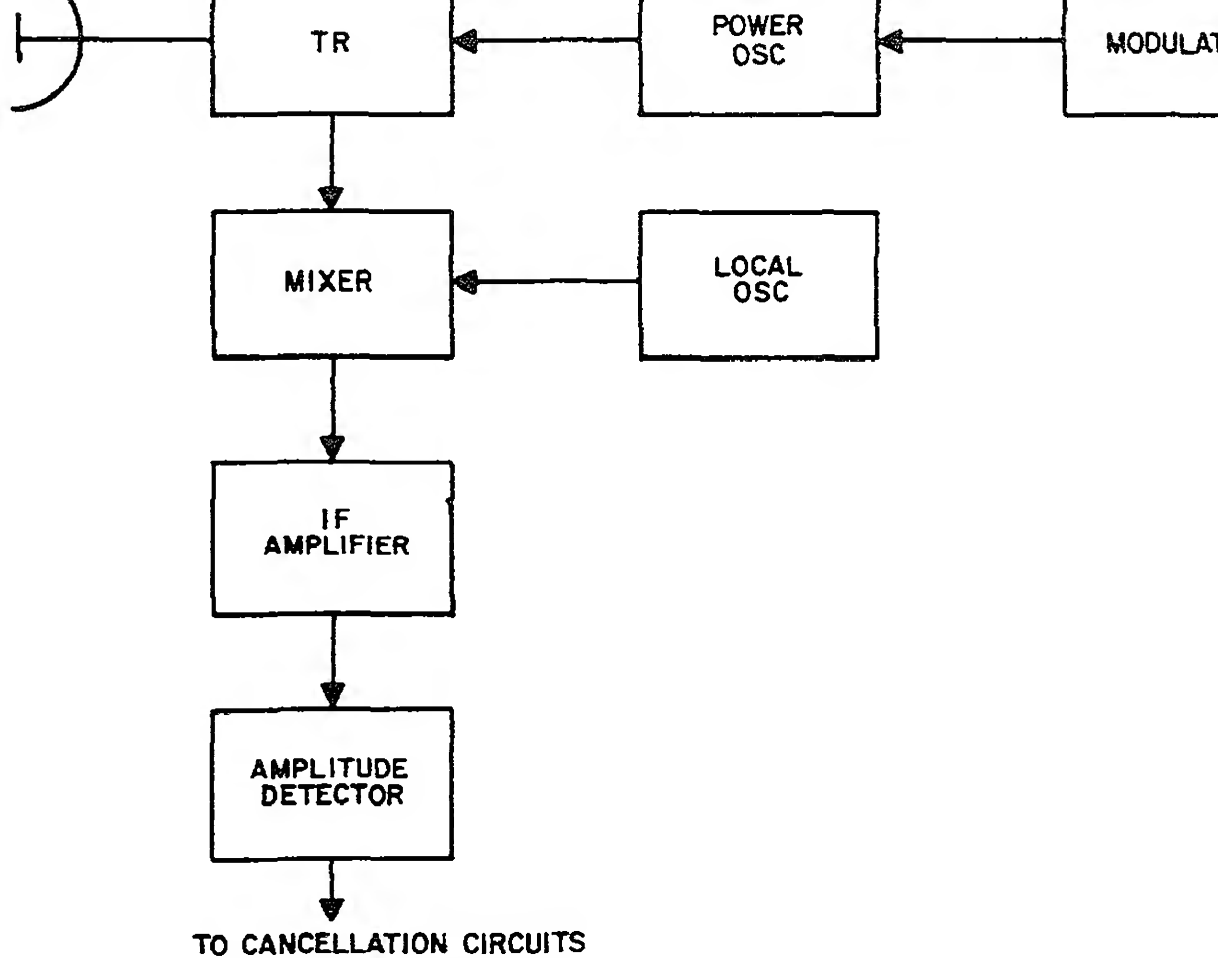
DELAY LINE CANCELERS

A. The a-m delay line canceler and the f-m delay line cancelers are the two types of cancelers in use.

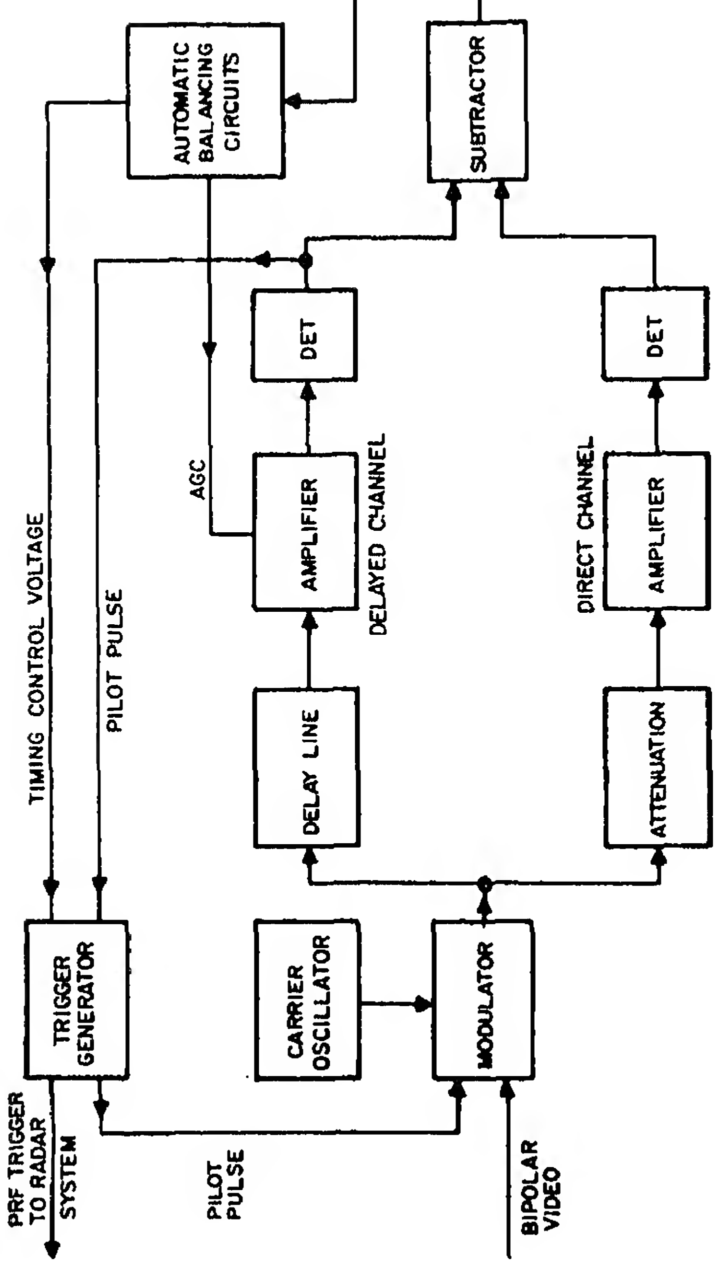
B. (Refer to figure 7.) The bipolar video from the phase detector is fed to an a-m modulator where it modulates carrier frequency. The modulated output carrier goes a delay line where it is delayed one prt; it also goes through the direct channel to a detector and then to a subtracter. The modulated carrier is subtracted from the modulated carrier caused by the previous prt. If the target represented where a moving target the bipol inputs would vary from prt to prt; in this case, the subtracter would have an output which would be sent through a full-wave rectifier to the video circuits. the target appeared stationary, the bipolar output of the phase detectors would not vary; therefore, both input to the subtracter would be equal resulting in no output.



AND MOVING TARGET VIDEO



BLOCK DIAGRAM OF BASIC NON-COHERENT MTI

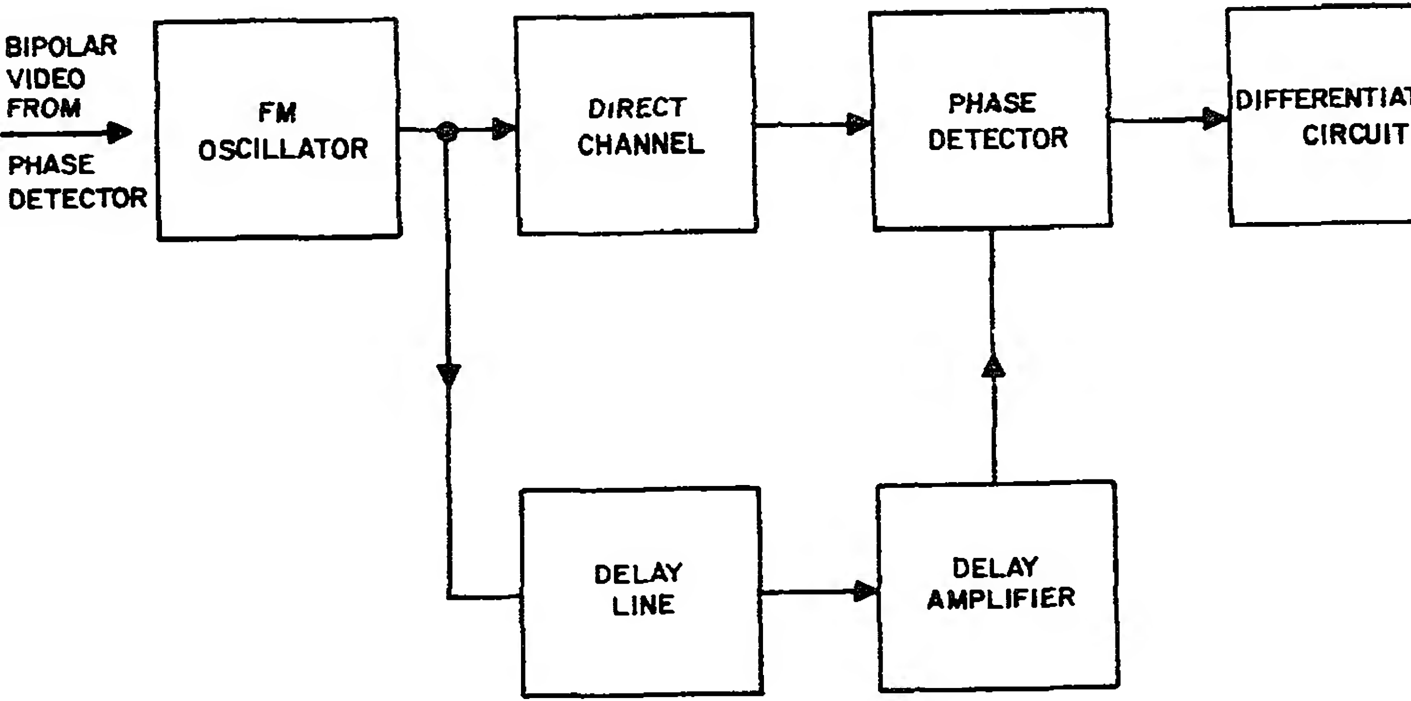

AUTOMATIC BALANCING CIRCUITS
SUBTRACTOR
TIMING CONTROL VOLTAGE
PILOT PULSE
AGC
DET
DET
AMPLIFIER
AMPLIFIER
DELAYED CHANNEL
DIRECT CHANNEL
DELAY LINE
ATTENUATION
TRIGGER GENERATOR
CARRIER OSCILLATOR
MODULATOR
PRF TRIGGER TO RADAR SYSTEM
PILOT PULSE
BIPOLAR VIDEO

tionary target. With a stationary target fed into
canceler the output should be zero. If there is an
put while these trigger pulses come into the subtracter
output causes the automatic balancing circuits to
y the age to balance the two channels.

f-m delay line canceler (refer to figure 8) is not
gued with the aforementioned complications. The
olar video is fed to an f-m modulator where it
quency modulates a carrier. The f-m signal takes the
ect route to the phase detector where it is compared
the previous signal; the f-m signal also goes to the
ayed channel where it is delayed and will be compared
the next incoming signal.

delays required in each of the delay line cancelers
usually in the milliseconds; therefore, magnetostric-
e delay lines cannot be used. The delay line will be
acoustical delay line. The most commonly used are
quartz and mercury delay lines.

PEEDS - In MTI when the target is traveling at a velocity that causes a Doppler shift equal to or a multiple fo the prf of the radar set the target appears stationary and is not seen by the MTI radar.


BIPOLAR
VIDEO
FROM
PHASE
DETECTOR
FM
OSCILLATOR
DIRECT
CHANNEL
PHASE
DETECTOR
DIFFERENTIAT
CIRCUIT
DELAY
LINE
DELAY
AMPLIFIER

.1 Given statements concerning the antenna pattern, scanning method and information provided when using a sector PPI, select the correct statement(s).

.2 Given statements concerning the antenna pattern, scanning method and information provided when using E-scan, select the correct statement(s).

.3 Given statements concerning the antenna pattern, scanning method and information provided when using ADI, select the correct statement(s).

.4 Given statements concerning the characteristics of the terrains affect on the received video in a phase scanning terrain avoidance system, select the correct statement(s).

.5 Given statements concerning the antenna pattern, scanning method and display useable in the terrain avoidance mode, select the correct statement(s).

.6 Given statements concerning the antenna pattern, scanning method and display useable in the terrain clearance mode, select the correct statement(s).

.7 Given statements concerning the antenna pattern, scanning method and display useable in the terrain following mode, select the correct statement(s).

.8 Given statements concerning the purpose of terrain avoidance radar, select the correct statement(s).

ASSIGNMENT:

ead: Information Sheet 11.10.1I

omplete: Student Activity Guide 11.10.1S

QUESTIONS: NONE

c. HSD

d. VDI

2. What information is provided by E-scan?

a. Range only

b. Range and altitude

c. Altitude only

d. None of the above

3. The ADI is part of what system?

a. VDIG

b. S-scan

c. Sector PPI

d. HSD

4. What type of antenna system can provide the ADI displa

a. Phased array

b. Pencil beam system

c. Fan beam system with the pencil beam

d. All of the above

5. Which of the following provides for level flight abov
terrain?

a. Terrain avoidance

b. Terrain clearance

c. Terrain following

d. All of the above

rrain avoidance

rrain clearance

rrain following

l of the above

of the following provides for nearly constant radar
de above the terrain?

rrain avoidance

rrain clearance

rrain following

l of the above

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Terrain features such as mountains and valleys can cause problems when the flight path crosses them especially at night or in inclement weather.

The terrain avoidance radar, sometimes called terrain clearance or terrain following radar, can provide to the ai craft displays an all weather view of the area in front of the aircraft.

ces:

NA-01-85ADA-1 NATOPS Flight Manual A6E

NA-01-85ADF-2-17 Radar Set
APQ-156 Principles of Operation

1. Contact analog display

a. Horizon line

(1) Is a line that separates ground and sky

(2) Is controlled by the INS (ASN-92) such t
depict pitch and roll motion and compare
the fixed markers on the side of the ind

b. Ground texture

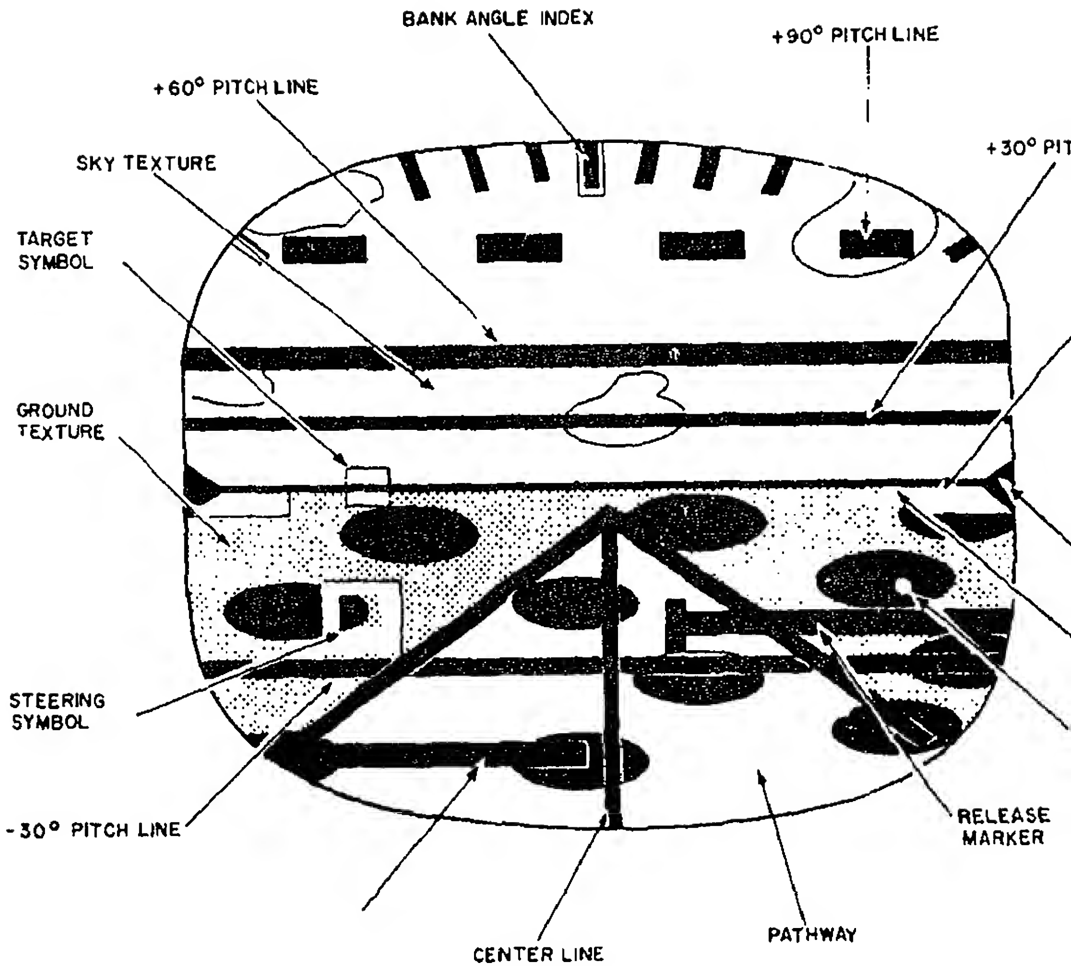
(1) Defines a ground plane readily distingui
from the sky texture and consists of ran
ground texture elements.

(2) Is controlled by the INS to depict headi
changes to the pilot

c. Sky texture

(1) Provides an additional real world refere
conjunction with the ground texture and
sists of random cloud symbols.

(2) Is also controlled by the INS to depict
changes.



CONTACT ANOLOG TEST DISPLAY
FIGURE 1

(3) The base of the path widens to indic
command altitude.

(4) In addition, when the aircraft is fl
correct heading but parallel to the
path, the base of the path moves ei
or right to indicate this condition

(5) If an attack pull-up maneuver is in
path apex assumes a pulled-up posit

(6) All information necessary for motio
flight path comes from the ASQ-115
Computer.

e. Centerline

(1) The centerline symbol is a dark lin
bisects the center of the path, and
dicates the center of the path.

(2) The centerline is visible only when
mand heading lines are not visible
in the perspective center regardles
motion.

f. Command heading lines

(1) Is composed of dark lines that pers
parallel the centerline.

(2) Three lines are always visible

(3) If a steering error exists, the com
heading lines rotate clockwise or c
clockwise around the path apex depe
the direction of steering error.

(2) The lines are manually positioned by the pilot with the PITCH TRIM control on the PCB so that the markers are coincident with the horizon line with the aircraft at a partic-ularlar angle of attack, so that he can re-turn to this attitude after completing his maneuver.

(3) The cursors are also positioned by roll in-formation from the INS to maintain the proper perspective when the aircraft rolls.

(4) The roll cursor is a single 3/4" white line extending down from the top perpendicular to the horizon line.

(5) Aircraft roll can be measured by comparing the cursor with the top fiducial markers which are spaced 10° apart and the farthest markers at 60°.

h. Impact point

(1) Consists of a bright circle that indicates the point where the aircraft would impact if it were to continue in its present attitude.

(2) When the angle of attack approaches a stall condition, the impact point blinks on and off at a rate of two times per second to indicate the pilot that a recovery maneuver is in order

(3) The blinking will also occur when the aircraft cannot pull the "G's" selected by the B/N on the computer.

(2) When a pitch line is at the vertical ce
of the display, the aircraft pitch angl
equal to the pitch line degree assignme

(3) Since the total elevation angle of the
is 30 degrees, and the pitch lines have
degree separation, no more than two pit
lines can appear simultaneously on the

(4) The distinction of recognizing one pitc
from the other is the physical characte

(a) The +30 and -30 degree pitch lines
identical, however they can readily
distinguished by noting the backgro

(b) With the aircraft at -30 degrees pi
the background texture consist enti
ground texture and with +30 degree
the background consists entirely of
texture.

(c) The +60 degree pitch line is consid
thicker than the 30 degree pitch l
and the +90° pitch line consists of
of dashes.

(d) Consequently the +60 and +90 degree
are readily distinguished from the
gree pitch lines.

j. Pull-up marker

(1) Is a solid black bar extending from
left edge of the path to the center
moves down the path in perspective.

impact.

k. Target symbol

(1) Consists of a bright solid square that indicates the ground plan position of the target.

(2) Information for positioning the target symbol is developed by the ballistics computer.

l. Weapon symbol

(1) Consists of a bright hollow square that presents "G" and roll commands to the pilot.

(2) Displacement of the symbol to the top of the display is the command to increase "G" and vice versa when displaced toward the bottom.

(3) Displacement to the right is the command to bring the right wing down and to the left to bring the left wing down. Therefore, these are roll commands.

(4) The ballistics computer provides the positioning signals for the weapon symbol.

m. Release marker

(1) Consists of a dark horizontal bar extending from the right side of the path and terminated by a short dark vertical bar in the center of the path.

(2) The marker indicates the time to release the weapon when it reaches the bottom of the display.

(3) The ballistics computer provides the positioning signal for the release marker.

b. This is accomplished by generating a hori
and 10 terrain profile lines, or range li
the display which represent 8.5 miles.

c. The range lines are representative of the
terrain ahead of the aircraft, and closel
that seen with the naked eye.

d. The height relationship between the range
the horizon line is a function of aircraf
and the actual terrain.

e. To create a real world dimensional effect
lines have varying brightness, that is, t
range line is the brightest while the far
the darkest.

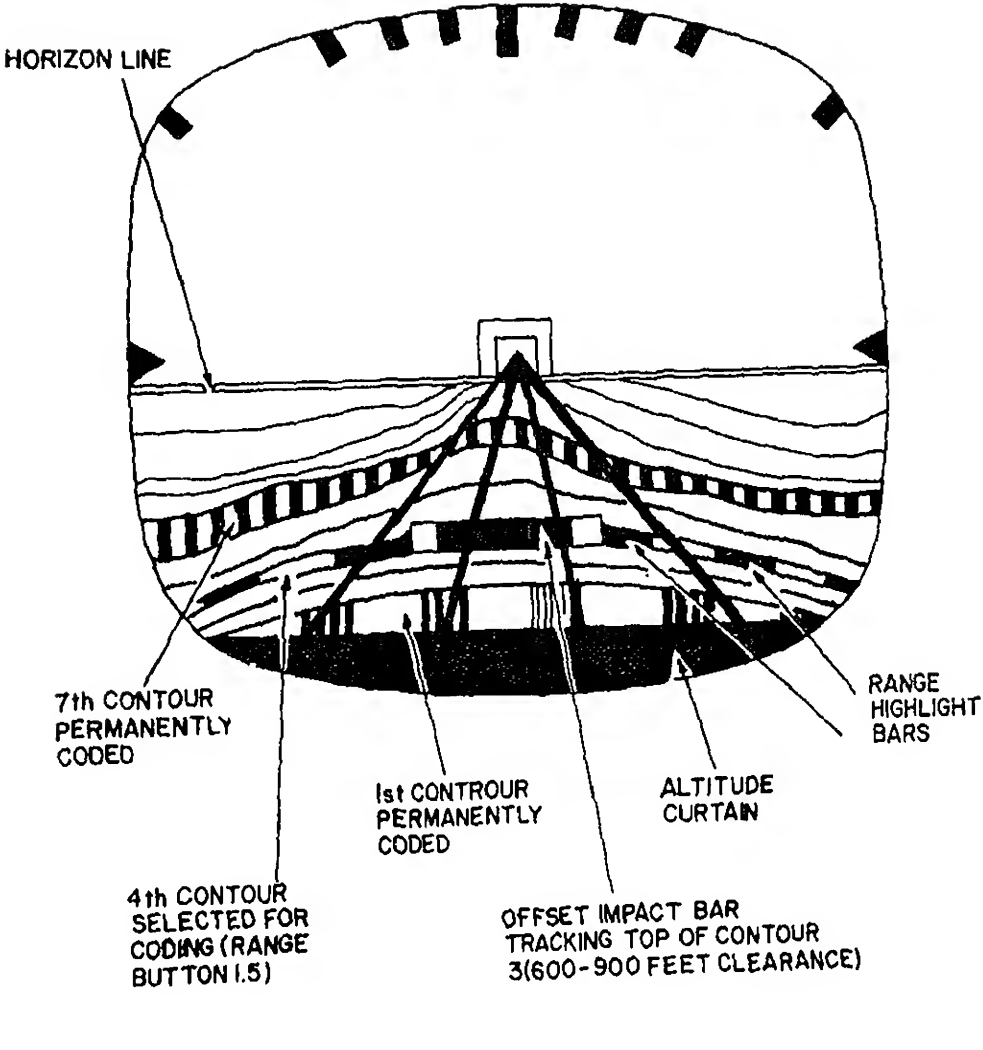
f. The symbols as seen on the display are as

(1) Highlight bar - series of vertical ba
allow the pilot to detect heading cha
the aircraft.

(a) First and seventh range lines are
lighted.

(b) Either the 3rd, 4th, 5th, or 6th
may also be selected for highligh
pilot utilizing positions 1, 1.5,
the RANGE MILES switch of the PCE

(2) Altitude curtain - is a blanking curt
appears at the bottom of the TC displ
the aircraft is approximately 600 fee
terrain. If the aircraft descends to
mately 20 feet, the curtain rises to
display and then disappears at 20 fee



Terrain Clearance Display
Figure 2

(b) Pitch information from the INS als
the marker in true perspective to
display.

(c) The pilot manually positions the m
some fixed range so as to maintain
craft so that the highest terrain
any closer than this fixed range.
called terrain avoidance flying.

(4) Calibration markers (confidence marker
two marker normally positioned at the
side of the display.

(a) The markers are located at -6° ref
and the other at zero degree (hori
reference, approximately 3/4 inche
the first marker.

(b) The purpose of these markers is to
to the pilot the degree of confide
can place by providing an instanta
continuous update indication of th
ing.

1) Elevation scaling, as indicate
vertical spacing between the m

a) If the spacing decreases,
rain display will appear t
a more gradual slope than
terrain.

b) If the spacing increases,
display will appear to hav
slope than the actual terr

2) Accuracy of the vertical range
ing, as indicated by the posit
markers.

a) If the markers rise before
normal position, the terra
displayed higher than it a
is.

3. Basic TC video processing (Figure 3)

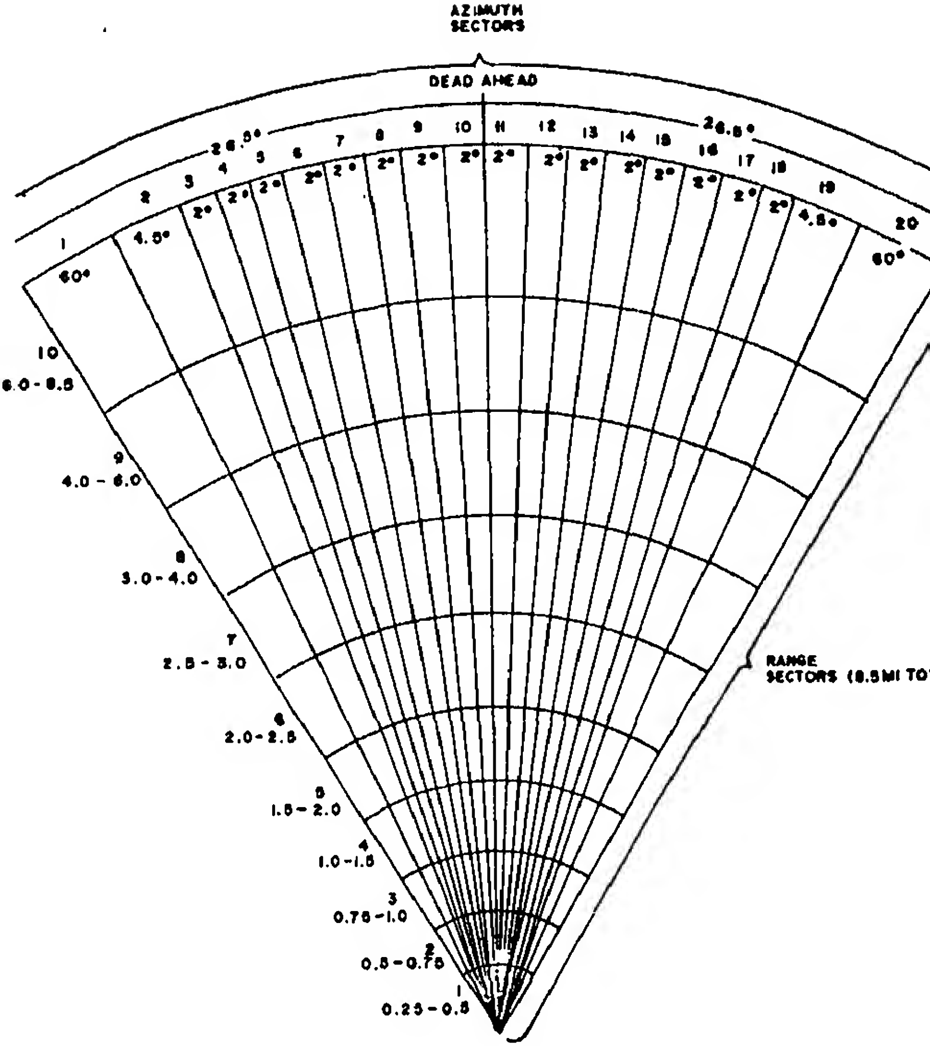
a. The TC storage circuits are composed of 200 storage modules arranged so that 10 rows represent range and 20 columns represent azimuth (antenna position).

(1) Range consists of 8.5 NM of video in 10 range bins.

(2) Azimuth consists of 53° of video in 20 azimuth bins.

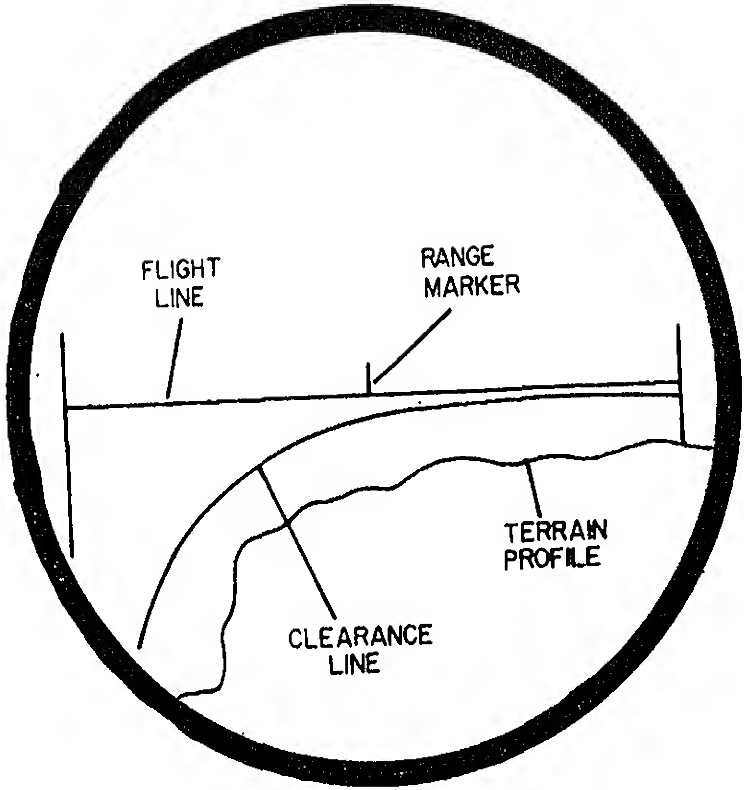
b. By reading out the stored range/azimuth information at a rate determined by the ADI horizontal and vertical frequencies, a suitable TC picture will be displayed on the ADI.

c. Note that the azimuth sectors are more narrow near the dead ahead azimuth bearing and are much wider near the azimuth extremes. This provides for the TC display to show more accurate terrain details ahead of the aircraft rather than at the edges where the terrain data is of less importance. This also holds true for the range distribution. The range sectors are smaller at the closer ranges than at the farther ranges where TC information is of less importance.



Basic TC Video
FIGURE 3

2. E-scan - used to show the Pilot where he is in respect to th altitude and range of targets dead ahead. (Figure 4)



A TYPICAL E-SCAN DISPLAY
FIGURE 4

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